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Petroleum Versus Alternate-Source Fuel Effects on Light-Duty Diesel Emissions

Southwest Research Inst., San Antonio, TX

Prepared for

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This report was furnished to the Environmental Protection Agency by Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, in fulfillment of Work Assignment 5 of Contract 68-03-3073. The contents of this report are produced herein as received from Southwest Research Institute. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

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FOREWORD

This project was conducted for the U.S. Environmental Protection Agency by the Department of Emissions Research, Southwest Research Institute. The laboratory testing phase of the project began in June 1982, and was completed in January 1983. The work was performed under EPA Contract No. 68-03-3073, Work Assignment No. 5, and was identified within Southwest Research Institute as Project 05-6619-005. The scope of work defined by the EPA is located in Appendix A of this report. The EPA Project Officer was Mr. Robert J. Garbe, and the Branch Technical Representative was Mr. Thomas M. Baines, both of the Characterization and Technical Applications Branch, Emission Control Technology Division, Environmental Protection Agency, 2565 Plymouth Road, Ann Arbor, Michigan. The Southwest Research Institute Project Manager was Charles T. Hare, and the Project Leader and Principal Investigator was Bruce B. Bykowski.

ABSTRACT

This report describes laboratory emissions evaluation of several alternate-source diesel fuels in a 1980 Volkswagen Rabbit. These evaluations are essentially a continuation of a previous study of several alternate-source fuels under EPA Contract 68-03-2884, Task Specification No. 3. The complete fuel matrix consisted of a No. 2 petroleum diesel fuel as base, mixtures of base fuel plus coal-derived liquids, shale oil diesel fuel, shale jet fuel, and a blend of petroleum stocks with coal and shale liquids. Two of the eleven fuels were evaluated during this latest project.

Vehicle operating procedures used for test purposes included those specified in Federal Regulations (FTP)(1)* and several steady-state modes. Both regulated and unregulated gaseous and particulate emissions were measured using a CVS-PDP and dilution tunnel operating on the entire exhaust stream of the engine. DOAS odor analysis was performed on raw exhaust samples during steady-state operation. Biological response evaluations, BaP measurement, and HPLC fractionation were conducted on the organic soluble portion of the particulate. The majority of the sampling and analytical procedures used were developed during earlier EPA Contracts 68-02-2494(2), 68-03-2707(3), 68-02-1230(4,5,), and 68-03-2440.(6)

After laboratory emission evaluations of the fuels were completed, the resulting data base, representing alternate-source fuels,was analyzed statistically along with data available in the literature representing petroleum-based fuels. Regression analysis was used to determine whether alternate-source materials affected exhaust emissions more strongly, less strongly, or to about the same extent as petroleum-based fuels.

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*Numbers in parentheses designate references at the end of the report.

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I. INTRODUCTION

The world's supply of crude oil is being depleted, creating incentives for discovery and utilization of alternate sources of fuels. Although interest has waned somewhat due to the current oil glut, it is considered important to continue research and development in preparation for the time when alternate-source fuels become a viable alternative. This study was designed to determine if alternate-source fuels, as currently available, will disproportionately affect exhaust emissions as compared to petroleum-based fuels. A light-duty diesel vehicle was used for test purposes. Diesel engines offer more sensitive evaluation of alternate fuel effects than gasoline cars do. No exhaust aftertreatment system has to be used on diesel automobiles to meet HC and CO standards for 1983, but a catalytic converter system is used on gasoline-fueled vehicles. Changes in diesel exhaust emissions due to alternate fuels thus affect the atmosphere and the recipient directly, but the catalyst on a gasoline vehicle tends to reduce the impact of changes in emissions seen in the raw exhaust.

This study continued the work performed under EPA Contract 68-03-2884, Task Specification No. 3. As discussed in that report(7), alternate fuel utilization and long-term research are basically still in their infancy due to the absence of large-volume production. Pilot plant yields are small, and the cost for pilot plant production of quantities suitable for testing in this program was prohibitive. Materials available in test quantities mostly represent first-generation alternate source materials. "First generation" refers to materials derived from alternate sources with little or no after-treatment, such as hydrogenation or catalytic cracking. In most cases, these currently available liquids did not have the specifications to run "as is." These liquids were blended with a petroleum base fuel to permit observation of any changes in emissions.

Selection of compounds used in both studies was made on the basis of availability, variety, and anticipation of second-generation compositions. Substances investigated include coal-derived liquids from the Solvent Refined Coal (SRC-II), Exxon Donor Solvent (EDS), and the Hydrocarbon Research (H-Coal) processes, shale oil products, a broadcut fuel containing n-butane among other stocks, and a mixture of coal, shale, and petroleum products.

A literature search was conducted to obtain published reports of technical papers presenting data on petroleum fuel effects on light-duty diesel emissions. The data from these studies and the data generated from the alternate source studies were normalized and statistically analyzed to present data in such a manner that a determination might be made as to the effects of alternate-source fuels on emissions as compared to petroleum fuels.

II. SUMMARY AND CONCLUSIONS

The major objective of this project was to determine if the effects of property variation in alternate-source fuels on exhaust emissions were the same, less pronounced, or more pronounced than the effects of property variation in petroleum fuels. This study generated exhaust emissions data using several alternate-source diesel fuels in a 1980 Volkswagen Rabbit. The same vehicle was used in an earlier study(7) to evaluate several other alternate-source fuels. Data from this study and the previous study(7) were combined to represent alternate-source fuel effects on light-duty diesel exhaust emissions. Data regarding petroleum fuel effects on light-duty diesel emissions were obtained by reviewing available studies found in a library literature search.

One of the major challenges in performing this work was to formulate a statistical analysis test plan which would strengthen the statistical arguments, while minimizing the number of assumptions and maximizing the applications of the conclusions. The data base available had some severe limitations which restricted the application of more advanced statistical concepts. These limitations were that experiments were performed at differing times, under differing test conditions, and with differing objectives. Due to these conditions, it was expected that only general trend information would be available at the conclusion of this project. Decisions on whether petroleum fuels and alternate-source fuels affected exhaust emissions similarly or differently were based on calculated chi-square values or goodness-of-fit statistics.

The most important observations and conclusions reached as a result of this project (not necessarily in order) are as follows:

1. SASOL middle distillate fuel was associated with exhaust emissions similar to those observed while evaluating a shale diesel marine fuel. In general, the SASOL fuel was associated with the same or slightly lower emission levels as compared to the base fuel.
2. The 25 percent H-Coal blend has properties and emission results similar to the 25 percent EDS blend (both coal-derived liquids). Both fuel blends were associated with increases in emissions.
3. It appears that further treatment of "first generation" coal liquids by hydrogenation or catalytic cracking would result in "second generation" materials which do not increase exhaust emissions. This conclusion is based on comparing results of "first generation" liquids (SRC-II, EDS, H-Coal) and "second generation" materials (shale diesel marine, Paraho JP-5, SASOL).
4. Review of various studies obtained by the library literature search indicated a wide variety of conclusions concerning fuel effects on exhaust emissions. In most cases, the primary conclusion appeared to be that the vehicle/engine type, followed by driving cycles, affected exhaust emissions on a g/km basis more than changes in fuel properties.

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5. Bivariate correlation coefficients indicated that the various studies reviewed were associated with differing types of fuel property-exhaust emission relationships. For a particular fuel property-exhaust emission data pair, it was not uncommon for the correlation coefficients to range from -0.166 to 0.908. Some of these data having poor correlations yielded linear regression equations whose slope was opposite that observed with other studies.

6. For each fuel property-exhaust emission data pair, data from the petroleum-based fuel studies were used to generate prediction equations. The alternate-source fuel properties were inserted into the equations to yield predicted emissions. The observed and predicted emissions were used to determine goodness-of-fit of the models. Based on these calculations, the effects of alternate-source fuels on exhaust emissions are statistically indistinguishable from those associated with petroleum fuels.

7. It is not recommended to use detailed statistical analysis to evaluate the effects of alternate-source fuels versus petroleum fuels on exhaust emissions using the currently available data. Reasons include lack of good data bases, poor correlation within available bases, and the apparent stronger effects of engine displacement and driving cycle on exhaust emissions. Comparisons between alternate-source and petroleum fuels should be performed with the raw data, unless an adequate statistical experimental design was formulated prior to program initiation.

III. TEST VEHICLE AND FUELS

The test vehicle used was the identical vehicle previously employed to evaluate other alternate-source fuels in a previous study(7), continuity being the primary concern. Fuel selection was directed principally by availability of alternate-source (non-petroleum) materials not evaluated under the previous alternate-source study. Alternate-source materials were analyzed thoroughly to establish the properties of each fuel in detail.

A. Test Vehicle

The test vehicle was 1980 Volkswagen Rabbit diesel. A description of the vehicle is provided in Table 1, and it was supplied to the Contractor by EPA for test purposes.

TABLE 1. DESCRIPTION OF TEST VEHICLE

Vehicle Model	Volkswagen Rabbit
Engine Model	Family D
Model Year	1980
V.I.N.	17A0926720
Engine No.	CK591126
Body Type	2-Door Hatchback
Inertia equivalent, kg (lb_m)	1021 (2250)
Transmission	5-speed manual
Displacement ℓ (in^3)	1.47 (90)
Cylinders	4
Power, kW (hp) @ rpm	(48) @ 5000
Injection System	Bosch
Combustion Chamber	Swirl Chamber
Compression Ratio	23:1
Distance on Vehicle, km	2806[a], 4980[b]

[a] at project initiation
[b] at project completion

Initially, the vehicle was driven 220 km for conditioning using the base fuel. Emission tests were conducted to determine whether or not any shifts had occurred in the baseline emissions observed during the previous study.(7) The test results are summarized in Table 2. Complete test results can be found in Appendix B, pages B-2 and B-3. The variability was considered satisfactory for the purpose of continuing evaluation of alternate-source fuels.

TABLE 2. COMPARATIVE EMISSIONS DATA, TWO STUDIES

	Average FTP Emissions	
	Earlier Study	Current Study
HC, g/km	0.31	0.29
CO, g/km	0.96	0.99
NO_x, g/km	0.66	0.70
Particulate, g/km	0.25	0.27
Fuel, ℓ/100 km	6.37	6.40

B. Test Fuels

Most of the available alternate-source fuels were previously evaluated under another project.(7) Two additional fuels evaluated during this project were a SASOL coal-derived middle distillate, and a blend of 25 percent H-Coal in base fuel (DF-2). Due to the good ignition characteristics of the SASOL fuel (reflected in its cetane number), it was run "as-is." The H-Coal material required blending with the base fuel to permit reasonable vehicle operation. A 25 percent blend was chosen to be consistent with the other two coal-derived blends previously tested (SRC-II and EDS). Complete fuel characterization was a part of this sutdy. Properties of all the alternate-source fuels tested in both the current and previous projects are listed in Table 3.

TABLE 3. FUEL PROPERTIES AND COMPOSITION.

Description	Base DF-2	Shale Diesel Marine	Paraho JP-5	Coal Case 5A	35% SRC-II	Broadcut Mid-Continent	25% SRC-II	25% EDS	25% EDS Naphtha	25% H-Coal	SASOL Mid. Dist.
Fuel Code (EM-	329-F	453-F	473-F	474-F	475-F	476-F	478-F	482-F	485-F	526-F	527-F
Cetane No. (D613)	50	49	45	42	31	35	38	44	45	42	50
Cetane Index (D976)	50	52	42	41	32	49	38	42	45	46	52
Gravity, °API @ 60°F	37.5	37.9	43.6	31.1	28.2	44.1	31.7	33.8	38.3	32.8	44.5
Density, g/mℓ @ 60°F	0.837	0.835	0.808	0.870	0.886	0.806	0.867	0.856	0.833	0.861	0.804
Carbon. wt. %	85.8	86.3	85.9	86.5	86.2	86.1	86.4	86.5	86.3	86.8	85.7
Hydrogen, wt. %	13.0	13.4	13.7	12.4	11.8	13.2	12.3	12.7	13.3	12.5	14.0
Nitrogen, ppm (oxid. pyrolysis)	48	5	<1	1600	3400	1000	2000	267	142	980	<1
Sulfur (1 amp), %	0.24	<0.005	0.005	0.100	0.31	0.17	0.23	0.16	0.28	0.21	<0.01
Calculated H/C, numeric	1.81	1.85	1.90	1.71	1.52	1.83	1.70	1.75	1.84	1.72	1.96
Carbon No. range (.G.C.)	8-24	9-20	10-15	9-24	8-20	3-24	8-20	8-20	7-20	9-20	10-24
Aromatics, vol. %	21.3	28.5	22.	34.9	47.0	16.2	39.9	36.4	25.5	37.2	24.0
Olefins, vol. %	1.7	2.1	2.	1.4	0.6	0.0	1.2	0.0	0.5	1.2	0.0
Paraffins, vol. %	77.0	69.4	76.	63.7	52.4	83.8	58.9	63.6	74.0	61.6	76.0
Viscosity, cs @ 100°F (D445)	2.36	2.61	1.38	3.08	2.53	1.53	2.45	2.37	1.76	2.31	2.14
Gum, mg/100 mℓ (D481)	14.3	0.3	1.4	38.8	89.7[b]	23.8	30.1	60.0	13.1	54.6	24.4
Total solids, mg/ℓ	7.4	0.3	--	--	13.1	--	7.2	3.1	1.2	16.3	0.8
Metals in fuel, x-ray	0[a]	0[a]	0	0	0	0	9ppm Fe	0	0	--[c]	0
Boiling Range, °C (IBP-EP,D86)	191-340	207-317	179-248	192-366	171-328	21-354	178-327	179-353	108-334	182-331	190-404
10% point	219	236	189	234	207	53	209	207	157	212	200
20% point	231	246	192	244	215	121	220	218	182	223	206
30% point	242	252	196	253	225	151	231	227	203	231	210
40% point	251	259	198	259	234	178	240	239	223	239	217
50% point	260	266	202	267	243	216	250	251	238	247	223
60% point	269	272	206	276	252	239	259	263	254	256	233
70% point	278	278	211	277	263	255	270	276	267	267	249
80% point	290	286	218	292	274	270	281	293	281	279	278
90% point	307	295	228	330	292	303	303	316	302	299	339
95% point	323	302	237	353	309	327	319	336	319	316	392
Residue, wt. % (D86)	1.3	1.0	1.5	1.5	1.0	1.0	1.0	1.5	1.5	1.0	1.0

[a] <10 ppm of Cr, Fe, No, Cu, Zn, and Mg; <70 ppm Pb; <100 ppm Al and Si

[b] Sample not dry after 1 hr. in steam lit block

[c] 38 ppm Fe, 14 ppm Cu, 21 ppm Cr, <60 ppm Pb

TABLE 3 (CONT'D). FUEL PROPERTIES AND COMPOSITION.

Substance	Base DF-2	Shale Diesel Marine	Paraho JP-5	Coal Case 5A	35% SRC-II	Boradcut Mid-Continent	25% SRC-II	25% EDS	25% EDS Naphtha	25% H-Coal	SASOL Mid. Dist.
Fuel Code (EM-	329-F	453-F	473-F	474-F	475-F	476-F	478-F	482-F	485-F	526-F	527-F
Boiling Range, °C (IBP-EP,D2887)	104-387	118-341	157-286	140-416		24-399	129-508	128-419	72-455	122-382	161-487
10% point	197	216	175	217		68	193	192	139	196	188
20% point	220	237	187	238		123	214	210	174	214	198
30% point	239	254	195	254		155	232	228	197	230	208
40% point	256	265	201	264		196	248	243	225	241	216
50% point	268	274	210	271		233	259	257	249	254	228
60% point	280	285	216	284		251	271	273	264	266	241
70% point	292	297	224	299		262	285	289	279	278	261
80% point	307	307	234	315		280	302	305	298	294	292
90% point	330	319	244	344		314	321	332	314	316	358
95% point	347	325	254	367		342	345	356	336	335	410
Residue, wt. % (D2887)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Composition, Volume %											
Kerosene											
Petroleum	0.0	0.0	0.0	17.3	0.0	22.0	0.0	0.0	0.0	0.0	0.0
JP-5	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JP-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel											
Petroleum	100.0	0.0	0.0	66.7	65.0	23.0	75.0	75.0	75.0	75.0	0.0
Shale DFM	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal	0.0	0.0	0.0	16.0	35.0	6.2	25.0	25.0	25.0	25.0	100.0
Light Cycle Oil	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0
LSR Naphtha	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.0
HSR Petroleum	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0
Shale	0.0	0.0	0.0	0.0	0.0	20.9	0.0	0.0	0.0	0.0	0.0
Coal (Simulated)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-Butane	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	0.0

[a] <10 ppm of Cr, Fe, NI, Cu, Zn, and Mg; <70 ppm Pb; <100 ppm Al and Si

IV. INSTRUMENTATION AND ANALYTICAL PROCEDURES

Analytical procedures and equipment used to measure regulated and unregulated emissions are described briefly in this section. These procedures were used in earlier EPA Contracts(2,3,6,7), and are routinely used in present-day emission testing.

A. Vehicle Operation and Smoke Measurements

The VW Rabbit was operated to simulate road experience on a 2-roll Model ECE-50 Clayton light-duty chassis dynamometer, of the type qualified for Federal light-duty certificaiton.(8) Inertia and power absorption settings used for all test work on this dynamometer were set to simulate operations of an earlier model VW Rabbit tested in a previous study.(7)

Care was taken to insure that the vehicle's fuel system was purged properly before testing of each fuel. All test fuels were withdrawn from individual 19 liter cans. Prior to test, a 2 liter sample of test fuel was used to run the vehicle, with the return line routed to a container subsequently discarded. After this purge, the vehicle was operated for approximately 30 minutes, followed by FTP and HFET driving cycles, to remove any residuals from other fuels, and to insure that the vehicle fuel system contained only the fuel to be tested.

Exhaust smoke measurements were made using an optical light-extinction smokemeter, of the type specified in Federal regulations for heavy-duty diesel engine smoke certification.(9) The smokemeter was mounted on a 51 mm (2 in.) O.D. tailpipe extension when in use. The control/readout unit for the smokemeter was mounted remote from the vehicle under test, and continuous recordings of smoke opacity were made concurrently with vehicle speed traces. Smoke measurements were made over the first 505 seconds of the cold-start FTP cycle, while the vehicle was operated on the chassis dynamometer. This procedure was developed for research purposes on an earlier EPA Contract, No. 68-03-2417.(10)

B. Regulated and Unregulated Gaseous Emissions

Regulated gaseous emissions of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) were collected and analyzed using procedures and equipment described in the Federal Register.(8) The method of hydrocarbon analysis was an updated version of that proposed, and eventually adopted for, the 1980 Federal Register.(9)

The unregulated gaseous emissions measured were aldehydes, phenols, and odor. Aldehydes were measured using the 2,4-dinitrophenylhydrazine (DNPH) method.(2) The method consists of withdrawing a continuous sample of dilute exhaust at a rate of 0.24 m^3/hr, and bubbling the sample through glass impingers containing DNPH in hydrochloric acid. This process forms the aldehydes, phenylhydrazone derivatives, which are eventually injected into a gas chromatograph equipped with a flame ionization detector for separation and identification.

Phenols were measured using the ether extraction procedure.(2) The first step was to collect dilute exhaust in impingers containing aqueous potassium hydroxide, at a rate of 1.02 m^3/hr. The contents of the impingers are acidified and extracted with ethyl ether, and are eventually injected into a gas chromatograph equipped with a flame ionization detector.

Exhaust odor was evaluated using the A. D. Little "Diesel Odorant Analytical System" (DOAS). The procedure used in this study was the same as used in previous studies(5,10), and described in detail in the final report on another study.(11) The vehicle was operated at 3 steady-state modes; idle, 50 kph, and 85 kph. Raw exhaust samples were taken for a specified time so that the required amount of exhaust would pass through the Chromosorb 102 traps. TIA (total intensity of aroma) values are defined by either:

$$\text{TIA} = 1 + \log_{10} (\text{LCO}, \mu g/\ell)$$

or

$$\text{TIA} = 0.4 + 0.7 \log_{10} (\text{LCA}, \mu g/\ell),$$

whichever generates the highest value. "LCO" represents liquid column oxygenates, and "LCA" represents liquid column aromatics.

C. Particulate Collection, Mass Rate, and Aerodynamic Sizing

Particulate collection for this project was performed using a 457 mm (18 inch) diameter by 5 m (16 feet) long dilution tunnel operating on total vehicle exhaust. Other associated equipment includes probes, pumps, and filter holders to withdraw and collect the particulate on filters, and a balance to determine the mass of particulate collected.

The dilution tunnel is identical to that used in a previous study.(7) A 114 mm (4.5 inch) probe was located at the downstream end of the tunnel. This large probe was used to withdraw a dilute exhaust sample at a rate of 3.4 m^3/min (120 SCFM) through a 500 x 500 mm (20 x 20 inch) Pallflex filter (Pall Corporation). The dilution tunnel used is shown schematically in Figure 1. Some of the equipment necessary for collecting particulate and relating it to undiluted vehicle emissions is not shown in the schematic. It includes a constant volume sampler (CVS) operating at a nominal capacity of 12.6 m^3/min (450 CFM) to withdraw and measure unsampled air/exhaust mixture, and the positive-displacement pump (capacity 3.4 m^3/min) used for the 500 x 500 mm filter system.

Particle sizing was accomplished using a radial-slot impactor. The impactor system contained stainless steel stages on which particulate matter was supposedly fractionated by size, and a final Pallflex backup filter. The impactor was locatd at the downstream end of dilution tunnel. In operation, each stage was placed on a plate such that the slots in each stage decreased in width from sample entrance down to the filter. Each stage was rotated 45 degrees so the particulate matter passing through the slots impacted on a solid portion of the following plate. Particle retention characteristics were

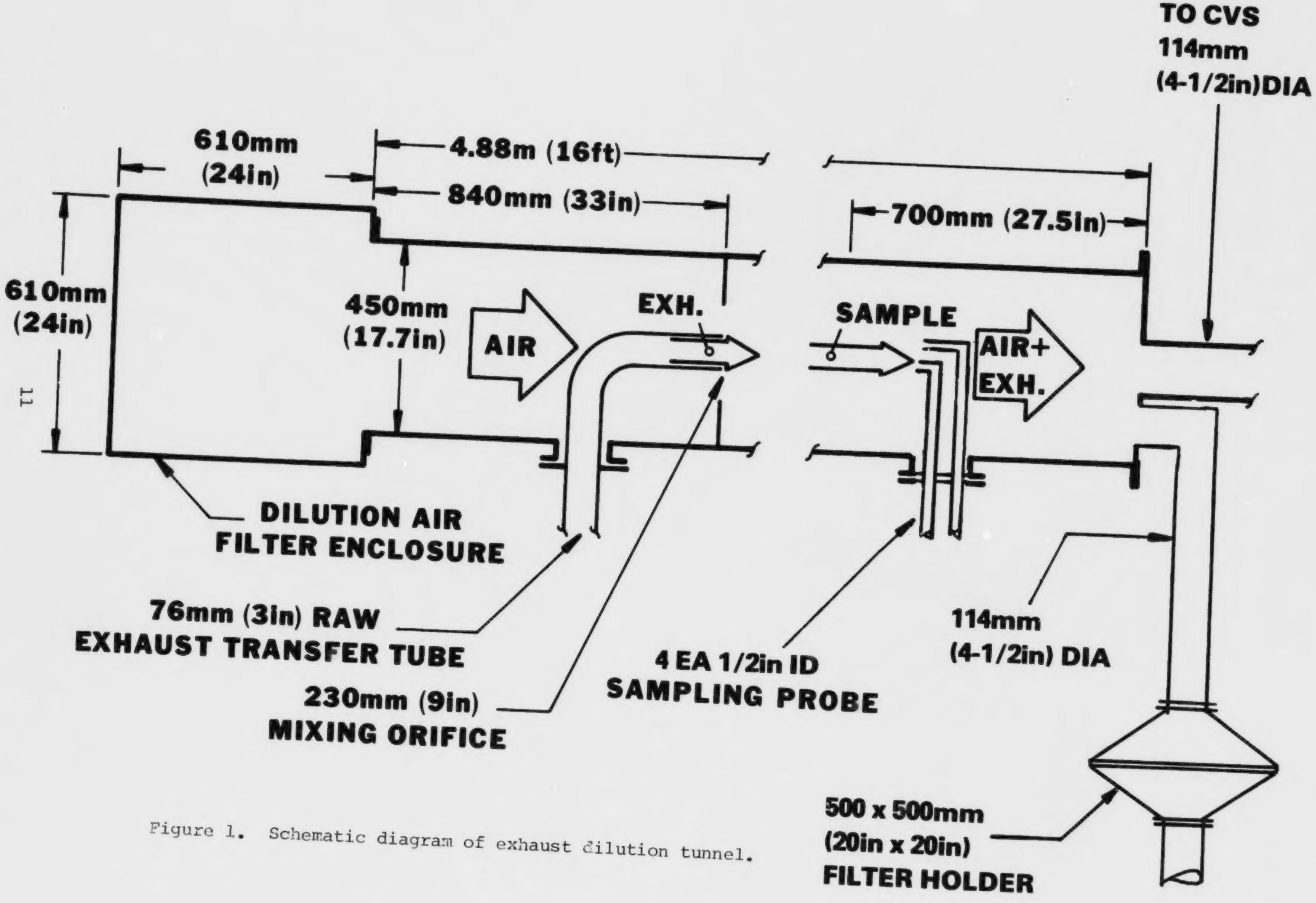
TO CVS
114mm
(4-1/2in)DIA
610mm
(24in)
4.88m (16ft)
840mm (33in)
700mm (27.5in)
610mm
(24in)
450mm
(17.7in)
AIR
EXH.
SAMPLE
AIR+
EXH.
DILUTION AIR
FILTER ENCLOSURE
76mm (3in) RAW
EXHAUST TRANSFER TUBE
230mm (9in)
MIXING ORIFICE
4 EA 1/2in ID
SAMPLING PROBE
114mm
(4-1/2in) DIA
500 x 500mm
(20in x 20in)
FILTER HOLDER

Figure 1. Schematic diagram of exhaust dilution tunnel.

related to the slot size and flowrate through the impactor. The flowrate was controlled using a metal bellows vacuum pump, pressure gauge, and flowmeter. The flowrate was maintained at 2.8 ℓ/min (0.1 CFM) to achieve particle sizing down to 0.1 micrometer.

The mass of particulate matter collected on sample filters and impactor discs was determined on a microbalance. This balance is enclosed in a vibration-resistant, temperature- and humidity-controlled chamber to minimize outside interferences. Filters and other materials for weighing were allowed to stabilize in the chamber for a minimum of 12 hours before they were weighed. The sensitivity of the balance is 1 µg. Air to the chamber flows at about 17 m^3/hr on a one-pass basis, and keeps the chamber pressure at about 2.5 kPa above atmospheric. The control system keeps chamber conditions at 22.2 ± 0.6°C and 63 ± 2 percent relative humidity, and air entering the chamber is filtered through a 99.99 percent DOP-efficient filter.

D. Analysis of Particulate Composition

Particulate samples were acquired by several methods for various analyses. After determining particulate matter weights, the samples were subjected to analysis for major elements and trace elements. Some particulate samples were collected in order to obtain the soluble fraction of particulate matter. Analysis of the soluble fraction is discussed in the next section.

1. Trace Elements

Analysis for trace elements (metals and sulfur) in the particulate matter was performed on 47 mm Fluoropore filter samples. As provided in the contract agreement, these determinations were made at EPA's Research Triangle Park laboratories as part of the EPA in-house measurement program. The instrumentation used for these analyses was a Siemens MRS-3 x-ray fluorescence spectrometer.

2. Major Elements

Samples collected on 47 mm glass fiber filters were sent to Galbraith Laboratories and analyzed for carbon and hydrogen content by combustion and subsequent gas analysis. The equipment used was a Perkin-Elmer Model 240B automated thermal conductivity CHN analyzer. Results of this analysis were reported in percent of submitted mass and calculated weight of element detected on the filter. These results make the filter weighing accuracy very important.

E. Analysis of the Soluble Fraction of Particulate Matter

The soluble fraction of particulate matter was obtained by extraction from the 500 x 500 mm (20x20 inch) Pallflex filters. This large filter enabled enough soluble material to be extracted so that the total amount could be divided into smaller aliquots, then analyzed for a variety of constituents.

1. Total Soluble Organics

The 500 x 500 mm filters were weighed before and after test to determine the weight of particulate matter. Each filter was extracted using methylene chloride in a Soxhlet apparatus. The solvent volume was reduced at low temperature and under vacuum. The remaining solvent/solubles were transferred to a preweighed container, and the solvent was evaporated by nitrogen purging. The total mass of solubles was determined gravimetrically, and the percent of solubles in the particulate matter calculated.

2. Major Elements

One aliquot of the dried, weighed soluble extract was submitted to Galbraith Laboratories and analyzed for carbon, hydrogen, oxygen, and sulfur by the technique and instrumentation described in Section IV, D.2 (Perkin-Elmer 240B). An additional aliquot of soluble extract was submitted to SwRI's U.S. Army Fuels and Lubricants Research Laboratory for nitrogen analysis by oxidative pyrolysis and chemiluminescence.

3. Solubles Boiling Range and Individual n-Paraffin Analysis

Another aliquot of soluble extract was submitted to SwRI's U.S. Army Fuels and Lubricants Research Laboratory for determination of the boiling range and reference to normal paraffins. The procedure is a high-temperature variation of ASTM D2887-73. Each aliquot was dissolved in carbon disulfide, and an internal standard (C_9 and C_{11} compounds) was added to quantitate results. The maximum temperature that this column reached was 450°C, eluting compounds boiling up to 650°C.

4. Benzo(a)pyrene (BaP) and Ames Bioassay

An additional 500 x 500 mm (20x20 inch) filter was extracted, and the extract was divided into eleven aliquots. One aliquot was used to determine the BaP content of the soluble extract. This analysis was performed by SwRI's Department of Emissions Research. The procedure, developed by others (12), is based on high-performance liquid chromatography to separate BaP from other organic solubles in particulate matter; and it incorporated fluorescence detection to measure BaP. The instrument used was Perkin-Elmer 3B liquid chromatograph equipped with a MPF-33 fluorescence spectrophotometer. Excitation was at a wavelength of 383 nm, and emission was read at 430 nm. The remaining ten aliquots were shipped on dry ice to EG&G for Ames bioassay testing. The Ames test refers to a bacterial mutagenesis plate assay with Salmonella typhimurium, according to the method of Ames.(13)

5. Fractionation by Relative Polarity

The composition of the organic soluble portion of the particulate matter is complex, and its separation into individual compounds is very difficult. Fractionation of the solubles by high performance liquid chromatography (HPLC) separates the sample into a series of fractions of increasing molecular polarity. This procedure is discussed in detail in a CRC report.(14)

Briefly, an organic solubles sample is initially carried in a solvent composed of 95 percent hexane and 5 percent methylene chloride, a relatively non-polar mixture. After a period of time, the ratio of methylene chloride to hexane, and therefore solvent polarity, is increased to a rate of 5 percent methylene chloride per minute. At 100 percent methylene chloride, the carrier solvent is moderately polar. A fluorescence detector is used at an excitation wavelength of 330 nm and an emission wavelength of 418 nm. A UV detector is used at wavelength of 254 nm. At these wavelengths fluorescence and UV responses of compounds are mapped as a function of column elution time, reflecting polarity.

V. TEST PLANS AND OPERATING SCHEDULE

The following section describes the vehicle operating schedules, exhaust analysis test plan, Quality Assurance Project Plan, and statistical analysis test plan. A summary of the exhaust constituents evaluated is given in Table 4. Discussion of the analytical techniques is presented in Section IV of this report.

A. Vehicle Test Plan

The vehicle followed two transient cycles, FTP and HFET, during most sample collection and measurement runs. These cycles are routinely used in emission testing and are well documented in other works.(1,3,6,10) Smoke evaluation was performed separately during the cold transient portion of the FTP (first 505 seconds). The cold transient portion incorporates all of the most interesting modes from a smoke standpoint, including cold engine start, first idle, first acceleration, second idle, and second acceleration. Steady-state modes at idle, 50 kph, and 85 kph were used to obtain raw exhaust samples for odor analysis. Vehicle running time on the steady-state modes was governed by the sample volume requirements of the odor measurement procedure (DOAS).

The test plan incorporating the cycles and evaluations for each test fuel is given in Table 5. Samples taken over each 2-bag FTP were defined as a "cold FTP" or a "hot FTP." Testing for each fuel required a minimum of three days. After the first day of testing, as many of the results as possible were reviewed to determine whether or not replicate analysis would be required on the second day of testing. It was important to determine the validity of the tests as early as possible, to avoid costly reruns and depletion of limited test fuel quantities by repurging the fuel system. Procedure for fuel system purging between test fuels is discussed in Section IV. Duplicate filter samples were collected on Day 2, and retained for possible replicate analyses. In some cases, samples were stored in their most stable form, then submitted for analysis as a group (rather than individually) to minimize the effects of day-to-day variability in an analytical procedure.

B. Quality Assurance Project Plan

A Quality Assurance Project Plan was prepared following EPA QAMS-005/80, entitled, "Guidelines and Specifications for Preparing Quality Assurance Project Plans," December, 1980. This project plan(15) was forwarded to the EPA in June 1982, prior to initiation of technical efforts.

A substantial portion of the program expenditures was made to prepare the Quality Assurance Project Plan. Costs for this effort were not originally included in the Work Plan. Therefore, some technical efforts originally planned were reduced to compensate for the Quality Assurance Project Plan efforts.

TABLE 4. OUTLINE OF CHEMICAL AND PHYSICAL EXHAUST EVALUATIONS

Exhaust Component under Study	Constituent(s) analyzed for	Collection Method	Analysis technique(s)
Smoke	smoke (visible	--	EPA smokemeter (continuous)
gases	HC, CO, CO_2, NO_x	sample bag	constant volume sampler
	aldehydes	wet impinger	DNPH
	odor	DOAS traps	DOAS sampler
	phenols	wet impinger	extraction, GC
particulate	total mass	Pallflex filters	gravimetric
	size distribution	impactor-filter	gravimetric
	sulfur & trace elements	filter, 47 mm Fluoropore	x-ray fluorescence
	carbon, hydrogen in particulate	filter, 47 mm glass fiber	combustion (commercial)
	organic extractable substances	"20x20" filter	soxhlet extraction
	BaP in organic solubles	--	LC, fluorescence detection
	molecular weight range of organic solubles	--	GC
	carbon, hydrogen in solubles	--	combustion (commercial)
	biological response of solubles	--	Ames bioassay
	polarity profile of solubles	--	HPLC

TABLE 5. TEST PLAN FOR EACH FUEL

Analysis or Sample	Day 1			Day 2[a]						Day 3 cold transient (505 seconds)
	Cold FTP	Hot FTP	HFET	Cold FTP	Hot FTP	HFET	Idle	50 kph	85 kph	
gaseous HC, CO, NO_x, CO_2	X	X	X	X	X	X	X	X	X	-
sulfur & trace elements	X	X	X	-	-	-	-	-	-	-
particle size distribution	X[b]		-	-	-	-	-	-	-	-
organic extractables[c]	X	X	X	-	-	-	-	-	-	-
total particulate mass	X	X	X	X	X	X	X	X	X	-
C & H in particulate	X	X	X	-	-	-	-	-	-	-
odor	-	-	-	-	-	-	X	X	X	-
aldehydes	-	-	-	X	X	X	-	-	-	-
phenols	-	-	-	X	X	X	-	-	-	-
BaP and Ames bioassay	-	-	-	X	X	-	-	-	-	-
smoke	-	-	-	-	-	-	-	-	-	X

[a] Repeat samples optional

[b] One sample collected for entire 4-bag FTP

[c] Organic extractables divided into aliquots for HPLC, carbon & hydrogen, and boiling range analysis

C. Statistical Anaylsis Test Plan

The principal objective of this study was to determine the degree to which alternate-source fuels affect exhaust emissions as compared to petroleum fuels. Several statistical approaches were available to meet this objective. Attempts were made to strengthen the statistical arguments while minimizing the number of assumptions and maximizing the applicability of the conclusions. It was not within the scope of the project to perform a detailed statistical analysis. However, the data were collected and treated in such a way that future efforts could continue with such analysis.

A literature search was conducted to obtain studies dealing with petroleum fuel property effects on exhaust emissions. Due to the wide variety of vehicles, fuels, test cycles, and measurement techniques used in previous studies, a method to relate all these studies in terms of general trends was developed. The data from all studies, on both petroleum and alternate-source fuels, were normalized to a selected fuel property level. Regression analysis was performed on each study's normalized data to yield linear equations for each selected (fuel property-exhaust emission) data pair. Analysis of the resulting line plots yielded general observations of trends for petroleum fuels versus alternate-source fuels. Bivariate correlation coefficients for each selected fuel property-exhaust emission data pair were also determined on each study. Goodness-of-fit was calculated by inserting the alternate-source fuel properties into the petroleum fuel exhaust emission prediction equations. These goodness-of-fit results were used to determine whether or not emission effects observed with property variation in petroleum fuels and alternate-source fuels differed statistically.

VI. GASEOUS AND PARTICULATE EMISSION RESULTS

This report section includes results and discussion on regulated gaseous emissions, aldehydes, phenols, exhaust odor, visible smoke, total particulate mass emissions, particle size distribution, and particulate matter elemental analysis. In addition, it includes information on organic solubles in particulate matter, elemental analysis of the solubles, BaP in solubles, boiling range of organic solubles by gas chromatograph analysis, polarity profile of the solubles, and bioassay analysis. Confidence limits could not be calculated due to an insufficient number of data points. Emission repeatability was good, with replicate results on the same fuel deviating five percent or less from the results of the first run. Exhaust emission results from the alternate-source fuels tested in the earlier study(7) are not reiterated in this section. Some of those results are presented with the data from petroleum fuel studies in Section VII.

A. Regulated Gaseous and Particulate Emission Results

Data on regulated gaseous emissions, including CO_2 and fuel consumption, were obtained by analysis of bag samples collected from the CVS-diluted exhaust. Particulate results were obtained concurrently by filtration of diluted exhaust. These results are summarized in Tables 6 and 7. They are reported for each individual bag, a calculated 3-bag FTP, and a calculated 4-bag FTP. The computer printouts for all the tests are located in Appendix C, pages C-2 through C-15.

TABLE 6. AVERAGE REGULATED GASEOUS EMISSIONS DATA

Fuel	Item	Emissions (g/km) and Fuel Usage (ℓ/100 km) by Driving Schedule									
		FTP Bag Number				(Calculated) 3-bag FTP	(Calculated) 4-bag FTP	HFET	Steady-State		
		1	2	3	4				Idle[a]	50 kph	85 kph
Base EM-329-F	HC	0.40	0.26	0.33	0.25	0.31	0.31	0.35	2.13	0.17	0.39
	CO	1.23	0.82	1.03	0.80	0.96	0.95	1.04	9.30	0.54	1.20
	CO_2	179.	164.	156.	163.	165.	165.	133.	1136.	124.	134.
	NO_x	0.67	0.67	0.64	0.66	0.66	0.66	0.61	5.78	0.53	0.67
	Fuel	6.94	6.33	5.95	6.32	6.37	6.36	5.17	0.44	4.77	5.22
SASOL EM-527-F	HC	0.51	0.21	0.39	0.18	0.32	0.31	0.23	1.56	0.14	0.24
	CO	1.43	0.88	1.21	0.82	1.08	1.07	1.25	7.95	0.54	1.38
	CO_2	174.	156.	150.	152.	158.	157.	132.	1125.	116.	129.
	NO_x	0.64	0.65	0.62	0.66	0.64	0.64	0.60	5.52	0.52	0.60
	Fuel	7.05	6.24	6.05	6.08	6.35	6.30	5.35	0.45	4.66	5.24
25% H-Coal EM-526-F	HC	0.50	0.31	0.35	0.22	0.36	0.33	0.39	10.74	0.38	0.35
	CO	1.33	0.97	0.97	1.06	1.12	1.15	1.28	24.69	0.79	1.12
	CO_2	184.	164.	158.	160.	166.	165.	143.	1067.	119.	143.
	NO_x	0.72	0.72	0.70	0.71	0.71	0.71	0.74	5.31	0.53	0.73
	Fuel	6.88	6.07	5.89	5.91	6.18	6.14	5.34	0.42	4.42	5.33

[a] Emission in g/h instead of g/km, fuel in ℓ/h instead of ℓ/100 km

The SASOL middle distillate fuel yielded gaseous and particulate emission results similar to the base fuel, EM-329-F, during the FTP. Fuel consumption was also unaffected. During the HFET, the SASOL fuel was

TABLE 7. AVERAGE PARTICULATE MASS EMISSIONS DATA

Fuel Code	Fuel Type	Grams Particulate per Kilometer				
		Calculated 1981 FTP	HFET	Steady-State		
				Idle[a]	50 kph	85 kph
EM-329-F	Base DF-2	0.25	0.25	0.71	0.17	0.28
EM-527-F	SASOL	0.23	0.25	0.42	0.14	0.27
EM-526-F	25% H-Coal	0.28	0.33	1.11	0.18	0.31

[a] Emissions in g/h instead of g/km

associated with a 34 percent reduction in HC, but a 20 percent increase in CO. A slight increase in fuel consumption was observed during the HFET. NO_x and particulate were essentially unaffected. The steady-state driving modes indicated that the SASOL fuel was generally associated with the same or slightly lower emission levels as compared to the base fuel. During the idle condition, particulate emissions with the SASOL fuel were about 41 percent lower.

Results with the H-Coal fuel blend, EM-526-F, indicated general increases in emissions and slight decreases in fuel consumption over both the transient cycles and all steady-states, as compared to the base fuel. The previous study(7) indicated similar results while testing a 25 percent EDS fuel blend. The EDS (Exxon Donor Solvent) material is a "first generation" coal-derived liquid produced by a process somewhat similar to the H-Coal process. Therefore, these results are not unexpected.

Of some interest is that data from the previous study(7) and this one have both shown that the "first generation" coal-derived materials tend to increase emissions. It was speculated in the earlier report that "second generation" materials would yield lower emissions than their "first generation" counterparts. The SASOL material, although not extracted from coal in the same way as the other coal liquids investigated, is an upgraded or "second generation" coal-derived fuel. This "second generation" material was associated with emissions similar to the base fuel. In the previous study, the upgraded shale oil liquids tested also yielded results similar to the base fuel. It is probable that further treatment of "first generation" coal-derived liquids by hydrogenation and catalytic cracking would result in "second generation" liquids which might not affect exhaust emissions adversely. This projection depends strongly on the degree of hydrotreatment used, and the desired quality of the end product.

B. Aldehyde and Phenol Results

Concentrations of several individual low-molecular weight aldehydes were determined in CVS-diluted exhaust. The results for each aldehyde species and their sums during the FTP are presented in Table 8. "Total" aldehydes refers to the sum of the individual aldehydes determined using the procedure discussed in Section IV. Table 9 represents the phenol results for the fuels tested. HFET results for both aldehydes and phenols are presented in Table 10. Aldehyde and phenol emissions for both alternate-source fuels were lower than those observed for the base fuel, regardless of driving cycle. These results were unexpected, and investigation into the analyses did not uncover any errors.

C. Results of Odor Analysis

This subsection contains results from instrumental odor evaluations (DOAS). The chromatographic procedure separates an oxygenate fraction (liquid column oxygenates, LCO) and an aromatic fraction (liquid column aromatics, LCA). Studies(11,16) have been made in an attempt to correlate instrumental analysis to a panel of trained human evaluators. One study(16) indicated that TIA (LCO-based) of less than 1.0 would be rated by a trained panel at less than "D"-1. A perceived odor intensity of "D"-1 by the Turk method is considered a light (barely perceptible) odor. It should be noted that since the TIA (total intensity of aroma) is calculated using a logarithmic equation, each increase of one unit in the TIA value relates to a concentration increase by a factor of ten.

Results of the odorant analysis are listed in Table 11. The TIA values (LCO-based) indicate that the SASOL fuel exhibited lower exhaust odorant levels than the base fuel. The 25 percent H-Coal blend, EM-526-F, was associated with higher exhaust odorant levels during the idle and 50 kph steady-state, but lower levels during the 85 kph steady-state condition. Similar results were reported in the earlier study(7) with the 25 percent EDS blend. In that study, the shale diesel marine resulted in lower odor levels than the base fuel.

D. Visible Smoke Emissions

Visible smoke was measured using an EPA-type smokemeter over the first 505 seconds (the "cold transient phase") of the FTP. Data taken on a 2-pen strip chart recorder consisted of vehicle speed and smoke opacity versus time. The traces, which were analyzed manually, are located in Appendix C, pages C-16 and C-17. The results, along with previously-run base fuel results, are summarized in Table 12.

These data show a marked increase of smoke during vehicle operation with the 25 percent H-Coal blend. Similar results were previously reported in the earlier study(7) with other coal-derived liquids. The SASOL fuel followed the trends reported with use of the Shale Diesel Marine fuel. During the cold-start and first acceleration, both fuels were associated with high smoke opacities as compared to the base fuel. During the second acceleration at 164 seconds, both fuels yielded lower smoke levels compared to the base fuel. Apparently, the Shale Diesel Marine and the SASOL combustion characteristics improve after vehicle warmup.

TABLE 8. FTP ALDEHYDE EMISSIONS DATA

Operating Schedule	Compound(s)	Concentration (mg/km) by Fuel Tested		
		Base EM-329-F	SASOL EM-527-F	25% H-Coal EM-526-F
Cold FTP	Formaldehyde	7.	0.0	0.0
	Acetaldehyde	2.	0.0	0.0
	Acetone[a]	2.	0.0	0.0
	Hexanaldehyde	0.0	0.0	0.0
	Benzaldehyde	0.0	0.0	0.0
	"Total"	11.	0.0	0.0
Hot FTP	Formaldehyde	10.	0.0	0.0
	Acetaldehyde	2.	0.0	0.0
	Acetone[a]	3.	0.0	0.0
	Hexanaldehyde	0.0	0.0	0.0
	Benzaldehyde	0.0	4.	0.0
	"Total"	15.	4.	0.0
Calculated 1981 FTP	Formaldehyde	9.	0.0	0.0
	Acetaldehyde	2.	0.0	0.0
	Acetone[a]	3.	0.0	0.0
	Hexanaldehyde	0.0	0.0	0.0
	Benzaldehyde	0.0	2.	0.0
	"Total"	14.	2.	0.0

[a] Includes acrolein and proponol

TABLE 9. FTP PHENOL EMISSIONS DATA

Operating Schedule	Compound(s)	Concentration (mg/km) by Fuel Tested		
		Base EM-329-F	SASOL EM-527-F	25% H-Coal EM-526-F
Cold FTP	Phenol	0.0	0.0	0.0
	Salicylaldehyde	0.0	0.0	0.0
	m-Cresol + p-Cresol	1.	0.0	0.0
	Group 5[a]	4.	0.0	0.0
	2,3,5-trimethylphenol	0.4	0.0	0.0
	2,3,5,6-tetramethylphenol	0.3	0.0	0.0
	2-n-propylphenol	7.	0.0	0.0
	"Total"	13.	0.0	0.0
Hot FTP	Phenol	0.0	0.0	0.0
	Salicylaldehyde	0.0	0.0	0.0
	m-Cresol + p-Cresol	0.1	0.0	0.0
	Group 5[a]	2.	0.0	0.0
	2,3,5-trimethylphenol	0.1	0.0	0.0
	2,3,5,6-tetramethylphenol	0.2	0.0	0.0
	2-n-propylphenol	8.	0.0	0.0
	"Total"	10.	0.0	0.0
Calculated 1981 FTP	Phenol	0.0	0.0	0.0
	Salicylaldehyde	0.0	0.0	0.0
	m-Cresol + p-Cresol	0.7	0.0	0.0
	Group 5[a]	3.	0.0	0.0
	2,3,5-trimethylphenol	0.3	0.0	0.0
	2,3,5,6-tetramethylphenol	0.3	0.0	0.0
	2-n-propylphenol	8.	0.0	0.0
	"Total"	12.	0.0	0.0

[a] Group 5 consists of p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

TABLE 10. HFET PHENOL AND ALDEHYDE EMISSIONS DATA

	Concentration (mg/km) by Fuel Tested		
Fuel Type	Base	SASOL	25% H-Coal
Fuel Code	EM-329-F	EM-527-F	EM-526-F
Phenols			
Phenol	0.0	0.0	0.0
Salicylaldehyde	0.0	0.0	0.0
m-Cresol + p-Cresol	1.	0.0	0.0
Group 5[a]	2.	0.0	0.0
2,3,5-trimethylphenol	0.03	0.0	0.0
2,3,5,6-tetramethylphenol	0.6	0.0	0.0
2-n-propylphenol	4.	0.0	0.0
"Total"	7.	0.0	0.0
Aldehydes			
Formaldehyde	9.	1.	0.0
Acetaldehyde	1.	0.0	0.0
Acetone[b]	5.	0.0	0.0
Hexanaldehyde	0.0	0.0	0.0
Benzaldehyde	0.0	0.4	0.0
"Total"	15.	1.	0.0

[a] Group 5 consists of p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethyphenol

[b] Includes acrolein and propanol

TABLE 11. RESULTS OF ODOR ANALYSIS AT STEADY STATES

Date	Fuel Code	Fuel Type	Condition	LCA, μg/ℓ	LCO, μg/ℓ	TIA	
						LCA	LCO
12/12/80	EM-329-F	Base DF-2	Idle	55.	3.7	1.6	1.6
			50 kph	110.	7.5	1.8	1.9
			85 kph	400.	21.	2.2	2.3
11/9/82	EM-527-F	SASOL	Idle	7.4	1.5	1.0	1.2
			50 kph	30.	1.4	1.4	1.1
			85 kph	28.	4.8	1.4	1.7
11/12/82	EM-526-F	25% H-Coal	Idle	47.	5.9	1.6	1.8
			50 kph	41.	17.	1.5	2.2
			85 kph	81.	7.3	1.7	1.9

TABLE 12. SUMMARY OF VISIBLE SMOKE DATA

Condition	Smoke Opacity, %, by Fuel		
	329	527	526
Cold Start Peak	21.2	54.0	61.0
Cold Idle, avg. (after start)	0.2	0.7	0.5
1st Accel. Peak	28.2	39.0	54.5
Idle at 125 secs., Avg.	0.7	0.1	0.5
Accel. at 164 secs., Peak	37.5	24.5	56.2

E. Particulate Size Distribution

Data from impactor runs were analyzed, and are presented as percentage of the total particulate mass by stage in Table 13. These data show that, as observed earlier[(7)], over half the particulate mass was composed of particles smaller than 0.2 µm. In the case of the SASOL fuel, almost 75 percent of the particulate mass was under 0.2 µm.

TABLE 13. PARTICULATE SIZE DISTRIBUTION

Run No.	Fuel Code	Fuel Description	Percent of Total Particulate									Vehicle Total Particulate g/cycle[a]
			Stage 3 9.5 µm[a]	Stage 4 5.8 µm[a]	Stage 5 3.7 µm[a]	Stage 6 2.1 µm[a]	Stage 7 1.2 µm[a]	Stage 8 0.8 µm[a]	Stage 9 0.5 µm[a]	Stage 10 0.2 µm[a]	Filter	
1	EM-329-F	Base DF-2	4.9	2.7	6.3	4.4	8.2	5.0	6.1	7.9	55.	5.81
2	EM-329-F	Base DF-2	6.8	6.3	2.0	2.3	5.7	2.3	2.7	6.7	65.	6.05
1	EM-527-F	SASOL	5.8	2.3	1.4	5.9	2.3	3.2	3.2	1.3	74.	5.13
1	EM-526-F	25% H-Coal	2.5	3.8	3.9	6.8	4.8	3.2	5.1	5.2	65.	7.21

[a] Based on 47 mm Pallflex for 4-bag FTP

F. Analysis of Particulate Composition

This subsection includes data on major elements and trace elements. Carbon and hydrogen analyses were performed on particulate collected using 47 mm glass fiber filters. Particulate collected on 47 mm Fluoropore filters was analyzed for trace elements.

Carbon and hydrogen data are listed in Table 14. As seen in earlier studies[(3,7)], the data show fairly high carbon and low hydrogen content, indicative of "dry" or soot-like particulate material. The analyses on the SASOL and 25 percent H-Coal blend were performed approximately a year later

TABLE 14. CARBON AND HYDROGEN IN EXHAUST PARTICULATE MATTER

Fuel Code	Fuel Description	Cycle	Weight Percent	
			Carbon	Hydrogen
EM-329-F	Base DF-2	FTP_c	81.6	2.8
		FTP_h	80.3	2.7
		HFET	83.6	2.9
EM-527-F	SASOL	FTP_c	92.8	2.7
		FTP_h	93.1	3.1
		HFET	91.4	2.9
EM-526-F	25% H-Coal	FTP_c	91.1	3.0
		FTP_h	92.5	3.1
		HFET	84.0	2.6

than those reported in the earlier study.(7) Results from both studies do not indicate any trends. As stated in other studies(3,6,7), the technique used to analyze carbon and hydrogen content of particulate collected on glass fiber filters appears somewhat questionable. A new procedure is needed to insure correct and accurate analysis of particulate collected on glass fiber filters.

Date on trace elements are given in Table 15. As a whole, these elements made up 0.3 to 2.1 percent of the particulate mass. The trace elements found most commonly in the particulate matter were sulfur, iron, nickel, calcium, and zinc. Possible sources of iron and nickel are wear products from the engine and exhaust system. Suflur, calcium, and zinc can probably be attributed to fuel sulfur and lubricating oil additives. Of some interest was the presence of a measureable amount of lead when the SASOL fuel was used during the cold-start FTP. The earlier study(7) reported lead only with the 25 percent SRC-II blend (a non-upgraded coal-derived liquid).

TABLE 15. PERCENT TRACE ELEMENTS IN PARTICULATE MATTER

Elements	Weight Percentage of Particulate Matter by Fuel and Cycle								
	EM-329-F Base			EM-527-F SASOL			EM-526-F 25% H-Coal		
	FTP_c	FTP_h	FET	FTP_c	FTP_h	FET	FTP_c	FTP_h	HFET
Mg	0.018	0.011	0.004	0.016	0.007	0.013	0.016	0.013	0.010
Al	0.025	0.009	0.003	0.012	0.005	0.005	0.014	0.004	0.005
Si	0.048	0.022	0.005	0.006	0.000	0.000	0.015	0.007	0.000
P	0.039	0.029	0.009	0.017	0.008	0.014	0.038	0.023	0.033
S	0.741	0.427	0.254	0.176	0.051	0.071	0.727	0.527	0.849
Cl	0.003	0.005	0.001	0.003	0.000	0.006	0.000	0.000	0.000
Ca	0.082	0.035	0.007	0.020	0.013	0.012	0.028	0.016	0.015
Ti	0.005	0.000	0.001	0.000	0.000	0.000	0.003	0.003	0.003
Fe	0.388	0.145	0.029	0.448	0.154	0.150	0.688	0.387	0.437
Zn	0.051	0.040	0.009	0.029	0.000	0.032	0.051	0.033	0.051
Sn	0.008	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Ba	0.004	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Cr	0.000	0.008	0.000	0.020	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.088	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000
Br	0.000	0.017	0.000	0.044	0.000	0.000	0.000	0.000	0.000
Cd	0	0	0	0	0	0	0	0	0
K	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Cu	0	0	0	0	0	0	0	0	0
Ni	0.096	0.016	0.005	0.092	0.000	0.020	0.058	0.019	0.021
V	0.000	0.000	0.001	0.008	0.000	0.008	0.000	0.008	0.006
Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mo	0	0	0	0	0	0	0	0	0
Total Percentage of Particulate	1.517	0.770	0.329	1.410	0.643	1.012	2.152	1.557	1.838

G. Composition of Organic Solubles in Particulate Matter

The organic soluble portion of the particulate was obtained from particulate samples collected on 20x20 inch Pallflex filters, using a Soxhlet extraction procedure (methylene chloride as solvent). A portion of the organic soluble material was analyzed for carbon and hydrogen. The results are given in Table 16. All of the elemental data for the FTP are indicative of hydrocarbon-like materials (numeric H/C ratio approximately 1.80). The SASOL and 25 percent H-Coal solubles yielded a numeric H/C ratio of about 1.5 during the HFET. This ratio is somewhat lower than reported in other studies.(3,6,7) Since extractions are performed with a relatively non-polar solvent (methylene chloride), the material extracted should be hydrocarbon-like. A pure hydrocarbon yielding a numeric H/C ratio of 1.15 would be made up of approximately 91 percent carbon and 9 percent hydrogen, with an emperical formula similar to benzene. The sum of carbon and hydrogen for the HFET's is approximately 88 percent. The remaining 12 percent could be speculated to be oxygen, but the aldehydes, phenols, and the analysis of the total particulate do not support this speculation.

TABLE 16. COMPOSITION OF THE ORGANIC SOLUBLE PORTION OF THE PARTICULATE

Fuel Code	Fuel Description	Cycle[a]	Weight Percent	
			Carbon	Hydrogen
EM-329-F	Base DF - 2	FTP	85.2	12.9
		HFET	85.5	12.9
EM-527-F	SASOL	FTP	84.3	12.0
		HFET	80.9	7.7
EM-526-F	25% H-Coal	FTP	82.8	11.0
		HFET	81.9	8.2

[a] "4-bag" FTP's

H. Gas Chromatograph "Boiling Range" Analysis of Organic Solubles

The organic soluble portion of particulate matter resembles a very heavy oil or a varnish. A high-temperature GC-simulated boiling point distribution, with an internal standard, was run on organic soluble material from particulate generated with each fuel. Table 17 summarizes the results for samples generated during both the FTP and HFET. The chromatograms for all of the samples summarized in Table 17 are located in Appendix C, Figures C-3 through C-6.

Both FTP and HFET results show that solubles from tests on the SASOL and 25 percent H-Coal test fuels show slightly lower boiling ranges as compared to the base fuel. The SASOL fuel gave a boiling range similar to that observed with the Broadcut fuel tested in the earlier study.(7)

TABLE 17. CHROMATOGRAPH ANALYSIS OF ORGANIC SOLUBLES IN PARTICULATE MATTER

	Boiling Temperature, °C, at Distillation Point by Fuel during 4-Bag FTP		
Fuel Description	Base DF-2	SASOL	25% H-Coal
Fuel Code	EM-329-F	EM-527-F	EM-526-F
IBP	318	253	269
10% point	365	342	337
20% point	388	377	353
30% point	416	406	395
40% point	451	428	420
50% point	494	452	449
60% point	537	479	482
70% point	605	512	522
80% point	-	564	603
90% point	-	-	-
EP	-	-	-
%Recovery @ 640°C	70.0	83.8	79.6

	Boiling Temperature, °C, at Distillation Point by Fuel during HFET		
Fuel Code	EM-329-F	EM-527-F	EM-526-F
IBP	325	278	262
10% point	374	353	341
20% point	400	396	376
30% point	429	418	410
40% point	462	438	437
50% point	492	460	464
60% point	526	482	493
70% point	582	510	530
80% point	-	555	603
90% point	-	-	-
EP	-	-	-
%Recovery @ 640°C	71.7	84.5	80.3

I. Fraction by Relative Polarity

Composition of the soluble organic fraction of the particulate is complex, and its separation into individual compounds is very difficult. Fractionation of the organic solubles by high performance liquid chromatography (HPLC) separates the soluble portion into a series of fractions of increasing molecular polarity. This procedure(14) is not quantitative, but provides a method to collect fractions with generally different polarities. All samples were analyzed at the same ratio of organic extract and carrier solvent. Therefore, the results can be compared to one another on a relative basis to estimate increases or decreases of compound classes which differ from each other by molecular polarity. Figures 2 through 5 show the HPLC chromatographic outputs for direct comparison of the relative response of increasingly polar compounds at the wavelengths discussed in Section IV, Part E-5 of the report.

Each figure contains three traces, one representing the carrier solvent composition, a second representing the ultraviolet detector response, and the

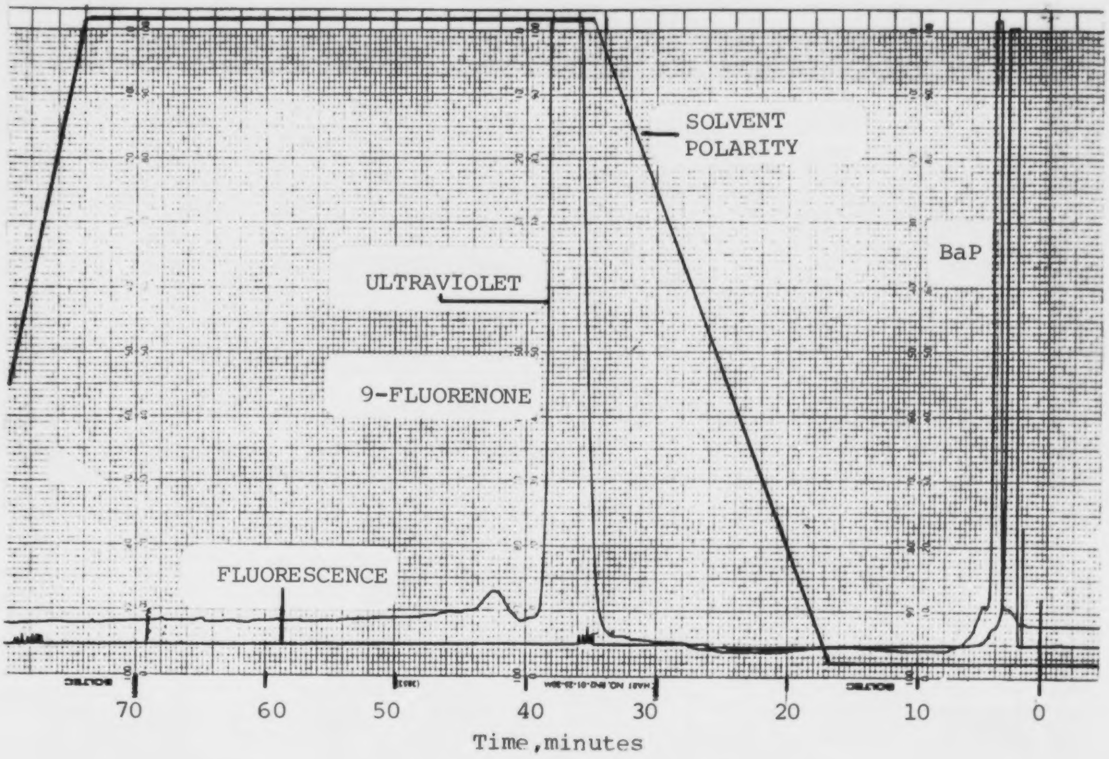

Figure 2. HPLC response to BaP and 9-fluorenone

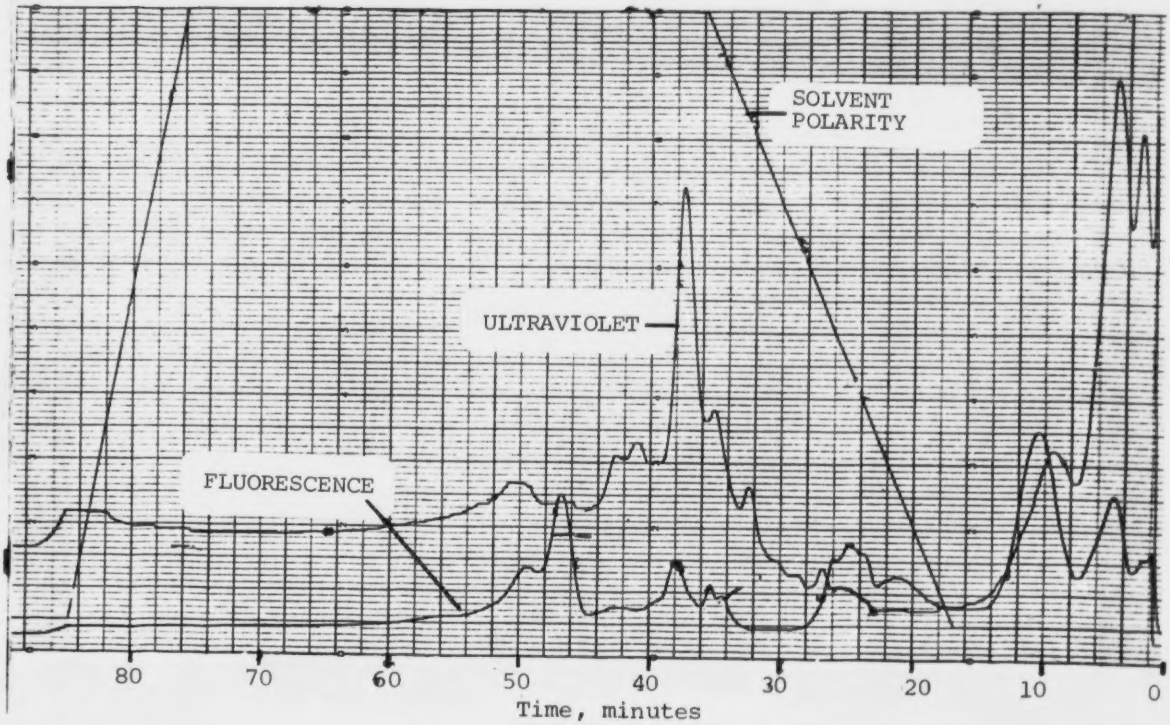

Figure 3. HPLC response to extract generated from base DF-2

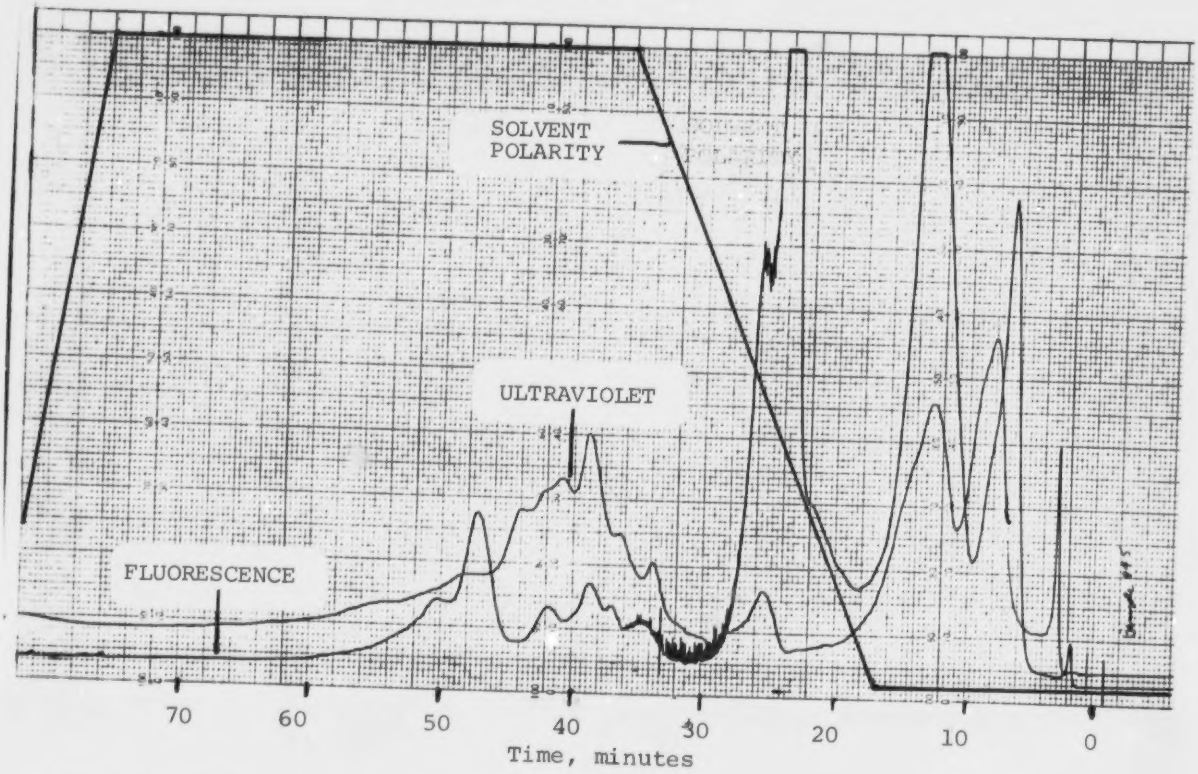

Figure 4. HPLC response to extract generated from SASOL middle distillate

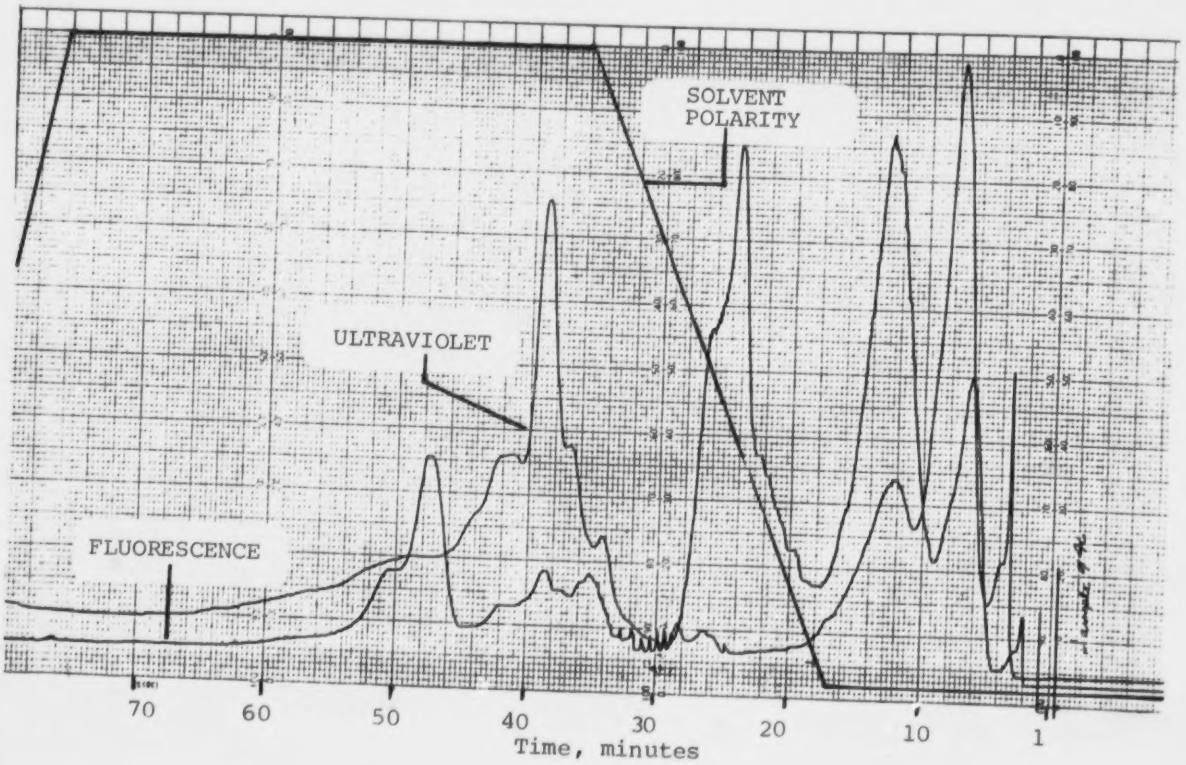

Figure 5. HPLC response to extract generated from 25% H-Coal

third representing the fluorescence detector response. Figure 2 shows the response of BaP and 9-fluorenone. BaP and similar compounds elute in this non-polar region. Near the end of the transition period (i.e., solvent polarity now polar), 9-fluorenone elutes. With 100 percent methylene chloride, even more polar compounds elute. For example, acridine elutes during this polar period (at about 70 minutes).

A CRC study(14) indicated that compounds which fluoresce in the transition fraction (at 20 to 30 minutes elution time, a fraction of intermediate polarity) yielded the highest Ames response (i.e., mutagenic activity). During this period, 20.9 percent of the Ames activity was associated with 2.5 weight percent of the organic soluble material. The greatest fluorescence response in this fraction (20 to 30 minutes elution time) was associated with the SASOL fuel. In the earlier study(7), the Paraho JP-5 (a shale oil fuel) yielded the highest fluorescence response. The H-Coal response was similar to the SRC-II blend reported earlier.(7) In summary, based on the results of the aforementioned CRC data and this study's fluorescence data, increases in Ames activity as compared to the base fuel might be projected for both the SASOL and the 25 percent H-Coal blend.

J. Benzo(a)pyrene (BaP) in Organic Solubles

BaP results are presented in Table 18 along with percentage of organic solubles in particulate matter. The BaP present in the organic soluble portion of the particulate for the fuels tested is substantially higher (about a factor of 10) than that found in other studies.(3,6,17) These results are consistent with those observed in the earlier study(17) using the same vehicle.

TABLE 18. BaP PRESENT IN ORGANIC SOLUBLES DURING $FTP_c + FTP_h$

Fuel Code	Fuel Description	Filter No.	Particulate g/km[a]	Percentage Extractables	% BaP in Extract	BaP µg/km
EM-329-F	Base DF-2	P20-82,83	0.25	14.6	0.042	14.9
EM-527-F	SASOL	P20-9,10	0.23	15.3	0.057	19.6
EM-526-F	25% H-Coal	P20-18,19	0.28	16.9	0.039	19.0

[a] based on 47 mm Pallflex

The BaP emissions for both the SASOL and 25 percent H-Coal blend were about 30 percent higher than those observed with base fuel. BaP emissions for most of the other alternate-source fuels tested earlier(7) were generally twice to three times the baseline levels.

K. Mutagenic Activity by Ames Testing

An additional amount of organic solubles representing each fuel tested was reserved for Ames bioassay analysis. The Ames test refers to a bacterial mutagenesis plate assay with Salmonella typhimurium according to the method of Ames.(13) The original test plan called for the Ames analysis to be performed by an outside laboratory under a separate EPA contract. Funding for this analysis was not included under Contract 68-03-3073, so it can not be performed at this time. It is anticipated that a new contract will be issued to complete these analyses, but it has not yet been finalized at this writing.

VII. STATISTICAL ANALYSIS OF FUEL AND EMISSIONS DATA

This report section discusses the application of several statistical computer programs to fuel and emissions variables. The principal goal was to determine, in a broad sense, the degree to which variation in alternate-source fuels affects exhaust emissions as compared to variation in petroleum fuels.

A. Statistical Methodology

Several approaches were developed to analyze data taken in the study and the data available in the literature. Alternate-source data from an earlier EPA study(7), this study, data available in previous EPA fuel variables work, and published literature were normalized to evaluate whether or not changes in emissions are affected by the source of the fuel (coal, shale, petroleum, etc.).

Originally, the prediction equations developed under EPA Contract 68-03-2707(3) were to be used in conjunction with the properties of the alternate-source fuels to yield predicted emissions, as if the alternate-source fuels were petroleum fuels. This study(3) used a Mercedes Benz 240D to evaluate petroleum fuel variation effects on exhaust emissions. The data from that study were subjected to multiple linear regression analysis to yield exhaust emission prediction equations as functions of fuel properties.

Requests to insert alternate-source fuel properties into petroleum fuel regression equations developed under Contract No. 68-03-2707 could not be answered straightforwardly without several critical assumptions. Due to the test designs of the two studies, they are essentially unrelated to each other because of vehicle differences (VW vs. Mercedes). Normalization of the Mercedes prediction equations would have involved a third study, in which both a Mercedes and a Volkswagen Rabbit were tested on the same fuels. This third study could have been used to determine the relationship between the two vehicles by determining a vehicle response factor, or equation which, when applied to Mercedes petroleum fuel prediction equations, would have resulted in petroleum fuel prediction equations for the VW. Insertion of alternate-source fuel properties into the VW equations would have yielded predicted emissions as if the fuels were petroleum-based. Comparison between these predicted values and the actual observed values using alternate-source fuels would have been used to determine if alternate-source fuel property variations were responsible for greater, lesser, or similar changes in emissions as compared to petroleum fuel property variations.

Determination of a vehicle response factor would have been difficult. In order to minimize the cumulative errors that would have occurred, the stuty conducted should have contained as many similarities as possible in terms of engine size, inertia settings, sample acquisition, analytical techniques, etc., to both the study which developed the Mercedes prediction equations and this current study. One study, performed at SwRI under Contract No. 68-03-2440(6), incorporated the identical Mercedes 240D used to develop prediction equations. The VW used in Contract No. 68-03-2440 was a different vehicle model year,

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although the engine displacement, inertia, horsepower setting, and transmission shift points were identical. Comparison of FTP emissions from the two VW Rabbits, both operated on "National Average" No. 2 diesel fuel (but different lots), showed that the vehicles did not respond similarly. If an assumption were made that the response difference was due to different diesel fuel lots, and that both VW's would respond identically if the exact same fuel were used, then the VW used in Contract No. 68-03-2440 could be used to determine a relationship between the Mercedes (petroleum-based prediction equation study) and the VW used in the alternate-source study.

Several other more critical assumptions would have been necessary. A vehicle response factor for each emission concerned would have been developed. The study under Contract No. 68-03-2440 did not result in prediction equations for most of the emissions with which we are concerned. At a minimum, the data in Contract No. 68-03-2440 would have been utilized again to establish some relationship between fuel properties and exhaust emissions for the Mercedes and VW Rabbit. If the relationships yielded equations containing the same fuel properties as variables, high R-squares, and low standard deviations, then the two vehicles could have been linked by some factor. If the resulting regression equations for the two vehicles were parallel, then a single vehicle response factor would have resulted. If the regression equations yielded non-parallel lines, then the vehicle response factor itself would have been in the form of another equation. Without this exercise to determine regression equations, a vehicle response factor for a particular point (i.e., one fuel property value) would have resulted. This resulting factor would have only been applicable to one point of the alternate-source fuel data, and general trends could not have been determined. Even if regression equations for both vehicles could have been determined, any error associated with each equation would have been cumulative, and would have eventually affected the final calculated VW prediction equations.

Assuming success to this point, two approaches existed. First, the vehicle response factor would have been applied to the Mercedes prediction equations determined in Contract No. 68-03-2707 to yield VW prediction equations. The accuracy of the Mercedes equations themselves would have to be verified first. Brief evaluation of the Mercedes prediction equations had shown poor prediction capabilities, however, due to a lack of population dispersion for fuels in that study.(6) Using these equations would have introduced additional error. The second approach involved using the prediction equations generated from the Mercedes/VW study (Contract No. 68-03-2440)(3), assuming that prediction equations were obtainable and that the 1977 model VW generated emission trends identical to the 1980 model VW, and inserting alternate-source properties into these equations to yield emissions as if the fuels were petroleum-based. This approach would have avoided probable errors that would have been introduced if vehicle factors had to be determined and then applied to the questionable Mercedes prediction equations. In any case, the procedures thus far discussed make many assumptions and introduce errors that may be large enough to invalidate any conclusions reached.

An alternate approach was reviewed to satisfy the objective of determining whether or not alternate-source materials affect exhaust emissions in the same way as petroleum fuels. This approach involved reviewing data available in previous EPA fuel variables work and other published literature to select studies that had some common element between the alternate-source study and petroleum studies. For example, studies chosen would incorporate a "base" fuel that is similar in properties. This criterion would reduce the number of studies to a workable matrix. The data from selected studies (about 12 were anticipated) would be grouped according to similar fuel property/exhaust emission interactions. For example, those studies which have shown a relationship between fuel aromatics and particuate emissions would be grouped together. Studies which resulted in a viscosity/particulate relationship would be in another group.

Each group would be treated separately. The data from each study within a particular group would be normalized to the "base" fuel for that study. The resulting normalization would express the various emissions data in terms of percent change from baseline data. The alternate-source study data would be treated similarly to determine if comparable changes in fuel properties would affect exhaust emisisons more, less, or the same as the results seen in studies dealing with petroleum base stocks.

In order to better visualize this approach, Table 19 presents mock data from studies reviewed and the alternate-source study. The following discussion is an example of what the table may be describing.

> "Table 19 shows the results of fuel aromatic content on particulate emissions. It should be noted that although an attempt was made to choose studies that began with a base fuel of similar properties, this was not the case for study D's aromatic content (study D was chosen for another fuel property matrix). Due to the apparent sensitivity of additional aromatics after a critical level, study D's results are not considered representative and comparable to the other petroleum fuel studies. Its data were therefore not included in averaging."
>
> "Another point to consider is that only study B incorporated a VW Rabbit. The other studies used different vehicles. The average, therefore, is affected by a variation in vehicle combustion characterisitics. Direct comparison between the average data from the alternate-source study with a VW Rabbit and the petroleum fuel study (study B) with a VW Rabbit showed that aromatic increases in the alternate-source materials did not affect particulate emissions."

The advantages of this approach would have been that no prediction equations were used directly (avoiding potentially high errors), vehicle response factors were not required, few assumptions were necessary, and a greater number of outside studies could have been used. Some disadvantages would have been that studies chosen may have had diverse base fuels which were not similar in properties. This situation would not have been apparent

TABLE 19. PARTICULATE EMISSIONS VERSUS FUEL AROMATIC CONTENT, MOCK DATA

Aromatic Content % Δ from Base	Particulate Emissions % Δ from Baseline Study						
	Alternate Source VW	Mercedes 240D	A	B	C	D[a]	Average[b]
1-25	0.1	0		0.5	--	10.	0.25
26-50	0.9	--	-1.0	5.	--	--	2.
51-75	4.	--	--	7.	--	40.	7.
76-100	8.	20.	10.	10.	10.	--	12.5
101-150	--	--	20.	30.	25.	--	25.
151-200	50.	--	--	40.	70.	--	55.
Average	12.6	--	--	12.5[c]	--	--	15.4[c]

---

[a] Study D base fuel's aromatic content was twice that of other studies
[b] Study D is not included in the average
[c] Average does not include 101-150% Δ aromatic content

"Conclusions:"

1. At each range of Δ aromatic content, the alternate-source materials were associated with a smaller increase in particulate emissions as compared to the average results of petroleum based fuel studies.

2. On the average throughout the aromatic content range, the alternate-source fuels were associated with about 18% less particulate emissions as compared to the average of all the petroleum-based fuel studies. Comparing the alternate-source study (VW) with study B (VW) shows that the alternate-source fuels did not affect particulate emissions.

3. Study D exhibited the greatest increase of particulate emissions with minimal change in aromatic content. Probable cause was the initially high aromatic levels of that study's base fuel.

when reviewing the table. Other parameters such as engine displacment and driving schedules would also have been "buried" in the table. The range of a particular fuel property may not have been evenly spaced to cover each study properly. These potential inconsistencies may have resulted in a table which contained only a few elements, and in any case, would have not shown any type of population dispersion.

A third approach, which incorporated some of the techniques of the two aforementioned approaches, involved both a visual representation and a prediction equation. Due to the wide variety of vehicles, fuels, test cycles, and measurement techniques used in previous studies, a method to relate all these studies in terms of general trends was adopted. This method involved reviewing each study dealing with petroleum fuels for emission trends. Those studies which indicated similar fuel property-exhaust emission relationships (primarily one-to-one relationships) were grouped together. The data from each study were normalized to a predetermined fuel property level (similar to National Average No. 2D). The normalized data set for each study was plotted on a common graph. The resulting graph showed emission trends as a function of petroleum fuel property with a variety of vehicles, base fuels, and driving cycles. A band encompassing the plotted data represented a population dispersion of petroleum-based fuel effects studies. Data from the alternate-source fuel study were also normalized and plotted on the same graph. Where the alternate-source study's line fell in relation to the petroleum-based fuel's band described the comparative effects of using alternate-source fuels.

Data from the petroleum-based fuel studies' band were subjected to linear regression analysis to determine an equation which represented all of the studies evaluated. This equation was used in conjunction with the alternate-source fuel study's fuel properties to yield predicted emissions based on petroleum fuel trends. Comparisons between predicted emissions and observed emissions from the alternate-source study were analyzed using chi-square test for goodness-of-fit, and conclusions were reached about alternate-source fuel effects on emissions as compared to average trends seen in petroleum-based fuel studies.

Other options may have existed to satisfy the objectives of this project. It was our opinion, however, that the third approach satisfied the objectives without involving too many assumptions or possible misrepresentation of the data. In addition, the third approach allowed for inclusion of as many studies as desired without their having to meet restrictive criteria. During a November 2, 1982 meeting at SwRI, the Branch Technical Representative approved the third approach. Past studies have shown that fuel property-exhaust emission relationships are not simple one-to-one correlations. Unless a test plan has been designed essentially without compromise, statistical analysis should not be overly complex, but should only be used in general terms to describe trends.

At the request of the Branch Technical Representative, an expanded discussion of the third approach to the statistical analysis (from a statistician's perspective) was written. Dr. Robert L. Mason of SwRI's Department of Fuels and Lubricants Technology assisted in the expansion and discussion of the third approach. His discussion is located in Appendix D, pages D-2 through D-5, for reference.

B. Raw Data Acquisition

Raw data representing the alternate-source fuels were obtained by combining results generated in this study with results reported in the earlier study.(7) Raw data representing petroleum fuels were obtained by performing a library literature search dealing with diesel fuel effects on emissions from light-duty vehicles. The initial search resulted in a listing of 37 references. These references were reviewed along with other available materials to determine which studies met basic criteria. Criteria for selection were: more than one petroleum-based fuel evaluated, adequate fuel analysis, exhaust emissions measurements, and use of a light-duty 4-stroke engine (<7 liters displacement). For example, studies dealing with the effects of methanol were not useful in satisfying the objective of this study. After review, a total of 9 references met the criteria. In those nine, a total of 15 test cases were available (some studies used multiple vehicles, and each vehicle was considered a test case). Studies used are listed as references 3, 6, and 18 through 24.

The statistical packages used for analysis of the data were SPSS (Statistical Package for the Social Sciences)(25) and BMDP (Biomedical Computer Programs).(26) Selected programs for each of these packages were used to evaluate the data.

C. Selection of Variables and Study Identification

The total number of fuel property and exhaust emission variables was too large to form a reasonable test matrix. During the November 2, 1982 meeting at SwRI, the Branch Technical Representative approved 8 fuel properties and 9 exhaust emission variables for further consideraiton. Fuel properties chosen were: density, aromatics, olefins, cetane number, gum, nitrogen content, 90 percent boiling point, and 10 percent boiling point. Exhaust emissions selected were: HC, CO, NO_x, particulate, fuel consumption, organic solubles, aldehydes, phenols, and BaP. Gum was later deleted from further consideration because only one study reported gum values for the fuels tested. This matrix was filled by data from the fuel studies selected.

In the nine petroleum-fuel studies, there were a total of fifteen cases of fuel property effects on exhaust emissions. The raw data for the studies available are listed in Appendix D, pages D-6 through D-8. At the request of its author, the raw data for Study H were not published; however, the normalized data were approved for publication. Each case was identified as a "Study ID" number. Cases conducted under the same study were identified by "Study Info". For example, B1 and B2 are both from the same study, but represent two different vehicle types, and therefore, two separate cases. Study K1 consists of data representing the alternate-source fuels.

The raw data from the petroleum fuels studied in each case were subjected to a bivariate correlation procedure to generate Pearson's correlation coefficients. Coefficients were determiend for "fuel property-fuel property", "emission-emission," and "fuel property-emission" relationships. All the coefficients were reviewed to determine trends depicted in all the test cases. Coefficients less than 0.700 were not considered as representing a usable correlation. A summary of the occurrence of coefficients greater than 0.700 is listed in Tables 20 through 22. The complete computer printout is too voluminous to include in this report.

Primary interest was in the fuel property-exhaust emission relationships. Another bivariate correlation procedure was performed on the alternate-source data. Raw data for this study are located in Appendix D, page D-8, as Study K. The fuel property-emission matrices for this study are shown as Table 23. Criteria for selecting fuel property-emission data pairs for further analysis were as follows:

1. Alternate-source study's data pairs which yielded coefficients greater than 0.700.

2. Data pairs in Table 20 which contained a large number of studies.

3. Data pairs which intuitively may have been related, but did not yield high coefficients.

Based on the above criteria, the fuel property-exhaust emission data pairs are shown in Table 24. The combination of data pairs covers most of the original fuel properties and exhaust emissions originally selected. Phenols were not analyzed further because only one petroleum study contained phenol analysis. Table 25 lists the Pearson correlation coefficients of the data pairs in Table 24 for all the studies.

D. Data Normalization

In order to account for the wide variety of vehicles, fuels, test cycles, and measurement techniques used in the various test cases, a method to relate all these cases in terms of general trends was developed. The exhaust emission data from all test cases were normalized to each of the selected fuel properties. The fuel property level was based on an average of several Phillips 2D Emissions Grade control fuel lot analyses. Averages were rounded for ease of insertion into calculations and data discussion. Fuel property analyses of the Phillips control fuel are listed in Table 26.

None of the test cases evaluated a fuel with the exact fuel property levels listed in Table 26. Therefore, linear regression analysis was performed on each of the selected fuel property-exhaust emission data pairs for each study case. The resulting equations were used in conjunction with the appropriate fuel properties from Table 26 to yield prediction of emissions. The prediction for each data pair and case was used to normalize (by division) the corresponding raw emissions data. This process could have resulted in

TABLE 20. NUMBER OF PEARSON CORRELATION COEFFICIENTS GREATER THAN 0.700 FOR FUEL PROPERTIES VS. EMISSIONS

	Number of Studies Where Coefficients were >0.9(1st digit), 0.9-0.8(2nd digit), 0.8-0.7 (3rd digit)								
	HC(9)[a]	CO(9)	NO_x(9)	Part.(9)	Fuel(9)	BaP(4)	Aldehydes(5)	Phenols(1)	Solubles(7)
Cetane(11)[a]	2,3,1	3,2,1	2,0,0	1,0,1	1,0,1	0,1,1	1,0,1	0,0,0	0,1,0
Density(11)	1,1,2	1,0,2	1,0,5	2,4,1	0,1,1	0,0,1	1,1,0	0,0,0	0,2,0
Nitrogen(3)	1,0,0	1,0,1	0,0,1	1,0,0	1,0,1	1,0,1	1,1,0	0,0,0	1,1,0
Aromatics(11)	2,0,1	3,1,0	2,0,0	1,5,2	1,0,1	0,1,1	1,1,2	0,0,0	0,0,1
Olefins(7)	1,0,2	1,1,2	0,1,2	1,0,1	1,0,2	0,0,0	0,1,0	0,0,0	0,0,1
BP 10%(11)	1,0,1	0,2,1	1,0,3	0,1,0	0,0,2	0,0,0	1,1,0	0,0,0	0,0,1
BP 90%(11)	1,0,2	0,1,1	2,0,1	0,0,1	0,1,1	0,0,0	1,1,0	0,0,0	0,0,0

[a] Number in parentheses is number of studies containing particular fuel property or emission

TABLE 21. NUMBER OF PEARSON CORRELATION COEFFICIENTS GREATER THAN 0.700 FOR FUEL PROPERTIES VS. FUEL PROPERTIES

	Number of Studies Where Coefficients were >0.9(1st digit), 0.9-0.8(2nd digit), 0.8-0.7(3rd digit)						
	Cetane(11)[a]	Density(11)	Nitrogen(3)	Aromatics(11)	Olefins(7)	BP 10%(11)	BP 90%(11)
Cetane(11)[a]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
Density(11)	0, 1, 3	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
Nitrogen(3)	0, 2, 1	0, 0, 0	---[b]	---[b]	---[b]	---[b]	---[b]
Aromatics(11)	1, 2, 0	4, 7, 0	0, 0, 0	---[b]	---[b]	---[b]	---[b]
Olefins(7)	1, 1, 0	1, 0, 2	0, 0, 0	0, 0, 2	---[b]	---[b]	---[b]
BP 10%(11)	0, 1, 0	2, 2, 0	0, 0, 0	1, 0, 1	5, 0, 0	---[b]	---[b]
BP 90%(11)	0, 1, 0	3, 0, 4	0, 0, 0	2, 0, 1	3, 0, 0	4, 0, 2	---[b]

[a] Number in parentheses is number of studies containing particular property

[b] Redundant values omitted

TABLE 22. NUMBER OF PEARSON CORRELATION COEFFICIENTS GREATER THAN 0.700 FOR EMISSIONS VS. EMISSIONS

	Number of Studies Where Coefficients were >0.9(1st digit), 0.9-0.8(2nd digit), 0.8-0.7(3rd digit)								
	HC(9)[a]	CO(9)	NO_x(9)	Part.(9)	Fuel(9)	BaP(4)	Aldehydes(5)	Phenols(1)	Solubles(7)
HC(9)[a]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
CO(9)	5,4,0	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
NO_x(9)	2,1,0	2,2,2	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
Part.(9)	1,0,1	2,0,0	0,1,3	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]
Fuel(9)	0,2,1	2,2,0	3,1,1	1,1,1	---[b]	---[b]	---[b]	---[b]	---[b]
BaP(4)	1,1,0	1,0,0	0,0,0	1,0,1	0,1,0	---[b]	---[b]	---[b]	---[b]
Aldehydes(5)	3,0,0	1,1,1	2,0,1	1,0,1	1,1,0	1,0,1	---[b]	---[b]	---[b]
Phenols(1)	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0	---[b]	---[b]
Solubles(7)	1,0,1	1,0,1	0,0,0	2,0,1	1,1,0	1,0,0	0,1,0	0,0,0	---[b]

[a] Number in parentheses is number of studies containing particulate emissions

[b] Redundant values omitted

TABLE 23. FUEL PROPERTY - EXHAUST EMISSION CORRELATION FOR THE ALTERNATE-SOURCE FUEL STUDY

	Pearson Correlation Coefficients							
	HC	CO	NO_x	Part.	Fuel	BaP	Aldehyde	Solubles
Cetane	-0.8873	-0.9221	-0.3262	-0.2938	-0.0669	-0.0800	0.1104	-0.5069
Density	-0.0563	-0.0123	0.7390	0.8059	-0.6205	-0.0365	-0.4577	0.4921
Nitrogen	0.6696	0.6556	0.5871	0.6672	-0.2254	0.0681	-0.3332	0.8149
Aromatic	-0.0864	0.0404	0.6483	0.8030	-0.6387	-0.0806	-0.7479	0.4817
Olefins	-0.2625	-0.3172	0.1202	0.2565	0.2369	0.2607	0.4099	0.0320
BP 10%	-0.6800	-0.6387	0.3149	0.4490	-0.4838	0.0583	-0.3021	0.0368
BP 90%	-0.1407	-0.1980	-0.0795	-0.0875	-0.4892	-0.1264	-0.5701	0.1157

TABLE 24. SELECTED FUEL PROPERTY-EXHAUST EMISSION DATA PAIRS

Fuel Property	Exhaust Emission
Cetane	HC
Cetane	CO
Cetane	Solubles
Density	HC
Density	NO_x
Density	Particulate
Density	Fuel
Nitrogen	CO
Nitrogen	BaP
Nitrogen	Solubles
Aromatics	HC
Aromatics	CO
Aromatics	NO_x
Aromatics	Particulate
Aromatics	BaP
Aromatics	Aldehydes
Olefins	Fuel
10% B.P.	HC
10% B.P.	NO_x
10% B.P.	Particulate
90% B.P.	HC
90% B.P.	Particulate

TABLE 25. PEARSON'S CORRELATION COEFFICIENTS FOR SELECT FUEL PROPERTY - EXHAUST EMISSION DATA PAIRS

Fuel Property	Exhaust Emission	Study Identification															
		A1	B1	B2	C1	D1	F1	F2	G1	G2	H1	I1	I2	J1	J2	J3	K1
Cetane	HC	-0.7618	-0.6425	-0.8297	0.9864	-0.6934	-0.9623	1.0000	-0.2962	0.8014	-0.3599			1.0000	1.0000	1.0000	-0.8873
Cetane	CO	-0.5405	-0.6213	-0.8848	0.9806	-0.8660	-0.9632	1.0000	-0.4325	0.7337	--	--	--	1.0000	1.0000	1.0000	-0.9221
Cetane	Solubles	-0.2560	0.5026	-0.8766	1.0000	--	--	--	-0.1599	0.1557	-0.2926	-0.1807	-0.2153	1.0000	1.0000	1.0000	-0.8873
Density	HC	0.7524	0.8307	0.6675	0.6990	-0.9265	0.7473	0.2842	0.2028	-0.6027	-0.2295	--	--	1.0000	1.0000	1.0000	-0.0563
Density	NO_x	0.7217	0.7273	0.1886	0.7780	0.9449	-0.2080	0.7125	-0.0262	-0.0387	-0.0974	--	--	1.0000	1.0000	1.0000	0.7390
Density	Particulate	0.8888	0.9870	0.8011	0.5553	-0.0751	--	--	0.0221	0.8915	0.4711	0.9233	0.7349	1.0000	1.0000	1.0000	0.8059
Density	Fuel	-0.0878	0.3993	0.4891	0.9513	0.4740	-0.8665	0.6533	-0.2198	-0.0766	0.2362	--	--	1.0000	1.0000	1.0000	-0.6205
Nitrogen	CO	0.0605	0.7342	0.9846	--	--	--	--	--	--	--	--	--	1.0000	1.0000	1.0000	0.6556
Nitrogen	BaP	-0.0313	0.7269	0.9744	--	--	--	--	--	--	--	--	--	1.0000	1.0000	1.0000	0.0681
Nitrogen	Solubles	-0.3506	-0.3042	0.9819	--	--	--	--	--	--	--	--	--	1.0000	1.0000	1.0000	0.8149
Aromatics	HC	0.7965	0.6360	0.6914	0.2487	-0.9993	0.9599	-0.2402	0.3877	-0.5090	-0.1339	--	--	1.0000	1.0000	1.0000	-0.0864
Aromatics	CO	0.9131	0.2347	0.5854	0.2739	-0.9494	0.9195	0.3542	0.8321	-0.3510	--	--	--	1.0000	1.0000	1.0000	0.0404
Aromatics	NO_x	0.6955	0.4237	0.2745	0.2608	0.9999	-0.6170	0.9696	-0.4444	-0.0711	0.2317	--	--	1.0000	1.0000	1.0000	0.6483
Aromatics	Particulate	0.8740	0.8939	0.8315	0.9084	-0.4102	--	--	-0.1657	0.7432	0.3697	0.8875	0.7058	1.0000	1.0000	1.0000	0.8030
Aromatics	Aldehydes	-0.3742	0.7120	0.8413	0.3866	0.9349	--	--	--	--	--	--	--	1.0000	1.0000	1.0000	-0.7479
Aromatics	BaP	0.1493	0.8568	0.7085	1.0000	--	--	--	--	--	--	--	--	1.0000	1.0000	1.0000	-0.0806
Olefins	Fuel	0.6246	-0.5565	-0.2942	-0.9698	-0.9999	-0.7033	-0.5684	--	--	0.2792	--	--	1.0000	1.0000	1.0000	0.2369
10% B.P.	HC	-0.4500	0.6997	0.3464	0.7088	-0.9707	-0.6874	1.0000	-0.4152	0.1499	-0.3230	--	--	1.0000	1.0000	1.0000	-0.6800
10% B.P.	NO_x	-0.0354	0.7283	0.5578	0.7962	0.9820	0.7225	-0.4617	0.4864	-0.0489	-0.2956	--	--	1.0000	1.0000	1.0000	0.3149
10% B.P.	Particulate	0.0735	0.8218	0.4826	0.5275	-0.2168	--	--	0.0880	0.3823	0.4420	0.2617	0.1076	1.0000	1.0000	1.0000	0.4490
90% B.P.	HC	0.0005	0.4973	0.1829	0.7481	-0.9794	0.7400	-0.1043	0.4744	-0.0734	-0.1842	--	--	1.0000	1.0000	1.0000	-0.1407
90% B.P.	Particulate	0.0817	0.7273	0.3294	0.5626	-0.2550	--	--	-0.2186	0.4946	0.4070	0.5768	0.4331	1.0000	1.0000	1.0000	-0.0875

TABLE 26. ANALYSES OF PHILLIPS 2D DIESEL FUEL LOTS

Property	EPA Specification	Phillips Lot No.			Average	Rounded
		C-345	C-504	C-747		
Cetane No.	42-50	47.8	46.3	47.5	47.2	47.
Distillation Range						
IBP, °C	171-204	196	200	197	198	200
10% point, °C	204-238	223	224	221	223	220
50% point, °C	243-282	264	257	263	262	260
90% point, °C	288-321	299	296	302	299	300
End point, °C	304-249	315	323	321	319	320
Gravity, °API	33-37	34.8	35.7	35.8	35.4	35.0
Density, g/mℓ		0.8509	0.8463	0.8458	0.8478	0.8500
Sulfur, %	0.2-0.5	0.30	0.25	0.20	0.25	0.25
Hydrocarbon Composition						
Paraffins, vol. %	---	65.	69.0	---	67.3	68.
Olefins, vol. %	---	5.	1.2	---	3.1	2.
Aromatics, vol. %	27 min	30.0	29.8	29.1	29.6	30.
Flash Point, °C min	54.4	79.4	75.0	69.4	74.4	74.
Viscosity, cs, 40°C	2.0-3.2	2.56	2.44	2.50	2.50	2.50
Nitrogen, ppm	---	---	80	---	80	80

a total of 352 normalization factors (16 cases, (15 petroleum + 1 alternate-source) x 22 selected fuel property-exhaust emission pairs). However, some studies did not report some of the selected fuel properties or exhaust emissions, so the actual total of normalization factors was 262. The normalization factors are listed in Table 27.

Application of the normalization factors to each raw data set (about two thousand simple divisions, plus re-establishment and storage of data files) was performed by a computer program written specifically for that purpose. The normalized exhaust emission data for each selected fuel property are listed in Appendix D, pages D-9 through D-29.

E. Scattergrams of Select Variables

The normalized data from each study were plotted on a common graph showing the emission of interest versus a specific fuel property. The petroleum-based fuel study data were plotted using the plot symbol "A", and the alternate-source study data used "B". A linear regression analysis was performed on the petroleum-based fuel data from all the studies to yield a single equation. This equation was used to superimpose a line on the common plot, representing the relationship between a particular petroleum-based fuel property and one exhaust emission variable. Similarly, a line representing the alternate-source fuels was also drawn on the plot. In addition, each plot contained a horizontal line representing a normalized emission value of 1.0, along with a vertical line representing the fuel property level to which the data were normalized. The effects of using alternate-source fuels were determined by observing where the alternate-source fuel line fell relative to the petroleum-based fuel line.

In addition, the normalized emissions data from each individual study were fitted with a least squares regression line using a specified fuel property as the independent variable. An equation was used similarly to fit the alternate fuel data. These lines were plotted on a common graph. The lines from the petroleum fuel data formed a region representing the dispersion for such studies. The effects of using alternate-source fuels were determined by observing where the alternate-source fuel line fell relative to the petroleum-based fuel band defined by the individual-study lines.

In all cases, the regression equation representing all the petroleum-based fuel data points was used (with the fuel property data from the alternate-source study) to obtain predicted emission values for comparison to the observed emission data from the alternate-source study. This comparison was accomplished using a goodness-of-fit statistic, defined as:

$$X^2 = \sum_{i=1}^{n} \frac{(\text{Observed} - \text{Predicted})^2}{\text{Predicted}}$$

Although "X^2" (as used here) is not a true chi-square statistic (as would occur in a single experiment with random observations), it is similar to the

TABLE 27. EMISSION NORMALIZATION FACTORS FOR SELECT FUEL PROPERTY - EXHAUST EMISSION DATA PAIRS

Fuel Property	Exhaust Emissions	Study Identification															
		A1	B1	B2	C1	D1	F1	F2	G1	G2	H1	I1	I2	J1	J2	J3	K1
Cetane	HC	0.124	0.148	0.318	0.200	0.240	0.875	0.479	0.101	0.260	0.771	--	--	0.369	0.329	0.135	0.333
Cetane	CO	0.576	0.639	0.592	0.790	0.880	1.022	1.213	0.418	0.762	--	--	--	1.251	1.047	0.709	1.095
Cetane	Solubles	27.811	29.807	34.614	71.600	--	--	--	26.086	39.439	37.27	181.473	68.590	163.619	101.976	41.338	45.244
Density	HC	0.151	0.169	0.388	0.288	0.169	1.722	0.434	0.130	0.033	0.428	--	--	0.353	0.305	0.131	0.398
Density	NO_x	1.053	0.833	0.608	1.536	0.844	0.411	1.099	0.963	0.818	2.019	--	--	0.873	1.259	0.651	0.732
Density	Particulate	0.311	0.342	0.277	0.300	0.179	--	--	0.117	0.176	13.233	0.563	0.255	0.282	0.209	0.276	0.299
Density	Fuel	9.560	8.985	5.883	8.958	7.917	4.918	12.877	10.125	11.552	128.30	--	--	8.596	10.219	10.636	6.357
Nitrogen	CO	0.521	0.625	0.550	--	--	--	--	--	--	--	--	--	--	--	--	1.106
Nitrogen	BaP	0.480	0.383	1.454	--	--	--	--	--	--	--	--	--	--	--	--	23.095
Nitrogen	Solubles	26.753	30.321	30.155	--	--	--	--	--	--	--	--	--	--	--	--	38.934
Aromatics	HC	0.123	0.168	0.418	0.264	0.197	1.094	0.367	0.125	0.098	0.660	--	--	0.330	0.269	0.125	0.400
Aromatics	CO	0.608	0.645	0.637	0.860	0.782	1.168	1.170	0.505	0.644	--	--	--	1.103	0.909	0.670	1.163
Armoatics	NO_x	0.938	0.826	0.597	1.412	0.834	0.409	1.047	0.946	0.818	2.145	--	--	0.844	1.265	0.645	0.718
Aromatics	Particulate	0.235	0.347	0.289	0.323	0.179	--	--	0.116	0.158	12.982	0.595	0.264	0.267	0.183	0.254	0.285
Aromatics	BaP	0.523	0.503	2.278	0.985	--	--	--	--	--	--	--	--	1.560	2.224	0.398	23.480
Aromatics	Aldehydes	0.974	19.794	35.948	33.247	28.621	--	--	--	--	--	--	--	11.462	7.296	0.307	6.494
Olefins	Fuel	9.592	8.757	5.787	8.426	7.563	4.150	10.738	--	--	124.69	--	--	8.494	10.409	10.709	6.474
10% B.P.	HC	0.085	0.171	0.357	0.288	0.178	0.240	0.648	0.080	0.269	0.209	--	--	0.309	0.240	0.119	0.356
10% B.P.	NO_x	0.854	0.840	0.619	1.533	0.840	0.492	0.936	1.054	0.816	1.939	--	--	0.821	1.271	0.539	0.721
10% B.P.	Particulate	0.188	0.345	0.268	0.299	0.178	--	--	0.118	0.160	13.176	0.522	0.226	0.254	0.163	0.236	0.292
90% B.P.	HC	0.101	0.149	0.300	0.270	0.249	0.785	0.372	0.130	0.198	0.638	--	--	0.345	0.292	0.127	0.405
90% B.P.	Particulate	0.209	0.319	0.245	0.291	0.181	--	--	0.115	0.153	12.878	0.436	0.220	0.276	0.199	0.269	0.278

chi-square; and the chi-square table was used to provide guidelines for determining whether or not the observed and the predicted values differed. A percentile value of $X^2_{.95}$, based on 9 degrees of freedom, was chosen from tables of the chi-square distribution to serve as a guideline value. If these had been true random observations, from a normal distribution, this value (16.9) would mean that decisions on whether petroleum-based fuel and alternate-source fuel effects were statistically different would have a 5 percent error rate.

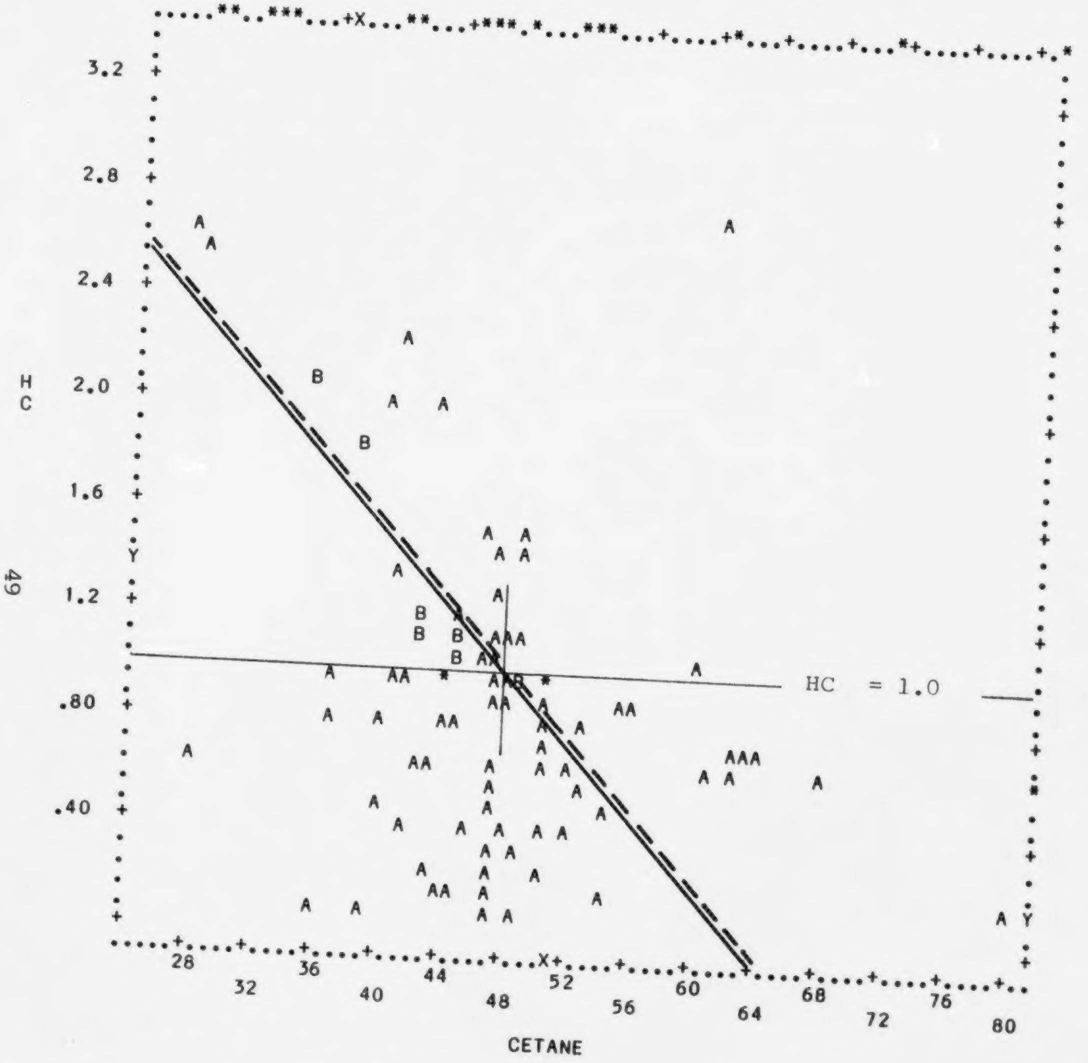
As stated in the Work Plan for this Assignment, the extent of statistical analysis possible depended on the funding available at the initiation of the data analysis portion of the work. As the analysis task began, it was apparent that a detailed statistical analysis was not possible due to efforts expended on the Q/A Project Plan and on attempts to formulate statistical approaches to analyze a greater number of fuel property/exhaust emission data pairs than originally anticipated. All the aforementioned analyses and data are included in this report as Appendix E. A detailed discussion of all the selected fuel property/exhaust emission data pairs was not feasible. Discussion on the regulated emissions (HC, CO, NO_x, and particulate) along with a few of the more interesting other results are presented using the goodness-of-fit technique to determine whether or not alternate-source fuels are different in affecting exhaust emissions as compared to petroleum-based fuels.

1. Hydrocarbons

Figure 6 shows the normalized data for both the petroleum-based fuels (A) and the alternate-source fuels (B) plotted in a common frame. The slopes of both lines are very similar, indicating that hydrocarbons respond to fuel cetane number independent of the type of fuel. The low correlation coefficient of the petroleum-based fuel data reflects variation by the individual study line plots among the petroleum-based fuel studies used; and this variation is further illustrated in Figure 7. These lines show that the alternate-source study K1 (dashed line) fell within the spread of the various petroleum-based studies.

Figure 6 includes the linear regression equation which represents data points from all the petroleum-based fuel studies. Using this equation and data from the alternate-source study, predicted emission values were calculated and compared to the observed emission data from the alternate-source study. Table 28 presents these results. The calculated "chi-square" (or goodness-of-fit, in this case) was 0.2376. The percentile value for a chi-square distribution with 9 degrees of freedom (number of data points - 1) for $X^2_{.95}$ is 16.9. Since 0.2376 is much smaller than 16.9, the "fit" of the data is very good, and therefore the observed values and predicted values do not appear to be different.

Figures 8 through 11 show the hydrocarbon data as a function of aromatics, density, 10 percent boiling point, and 90 percent boiling point, respectively. The line plots of the individual studies (similar to Figure 7) are located in Appendix E. Table 29 presents the goodness-of-fit (chi-square)



Petroleum
Solid Line

```
N=   85
COR=-.276

    MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X   47.424    8.3294   X=-1.1745*Y+ 48.644    64.882
Y   1.0390    1.9545   Y=-.06467*X+ 4.1058    3.5724
```

Alternate
Dashed Line

```
N=   10
COR=-.887

    MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X   44.000    4.9889   X=-11.360*Y+ 57.713    5.9547
Y   1.2072    .38969   Y=-.06931*X+ 4.2568    .03633
```

Figure 6. Normalized HC versus cetane.

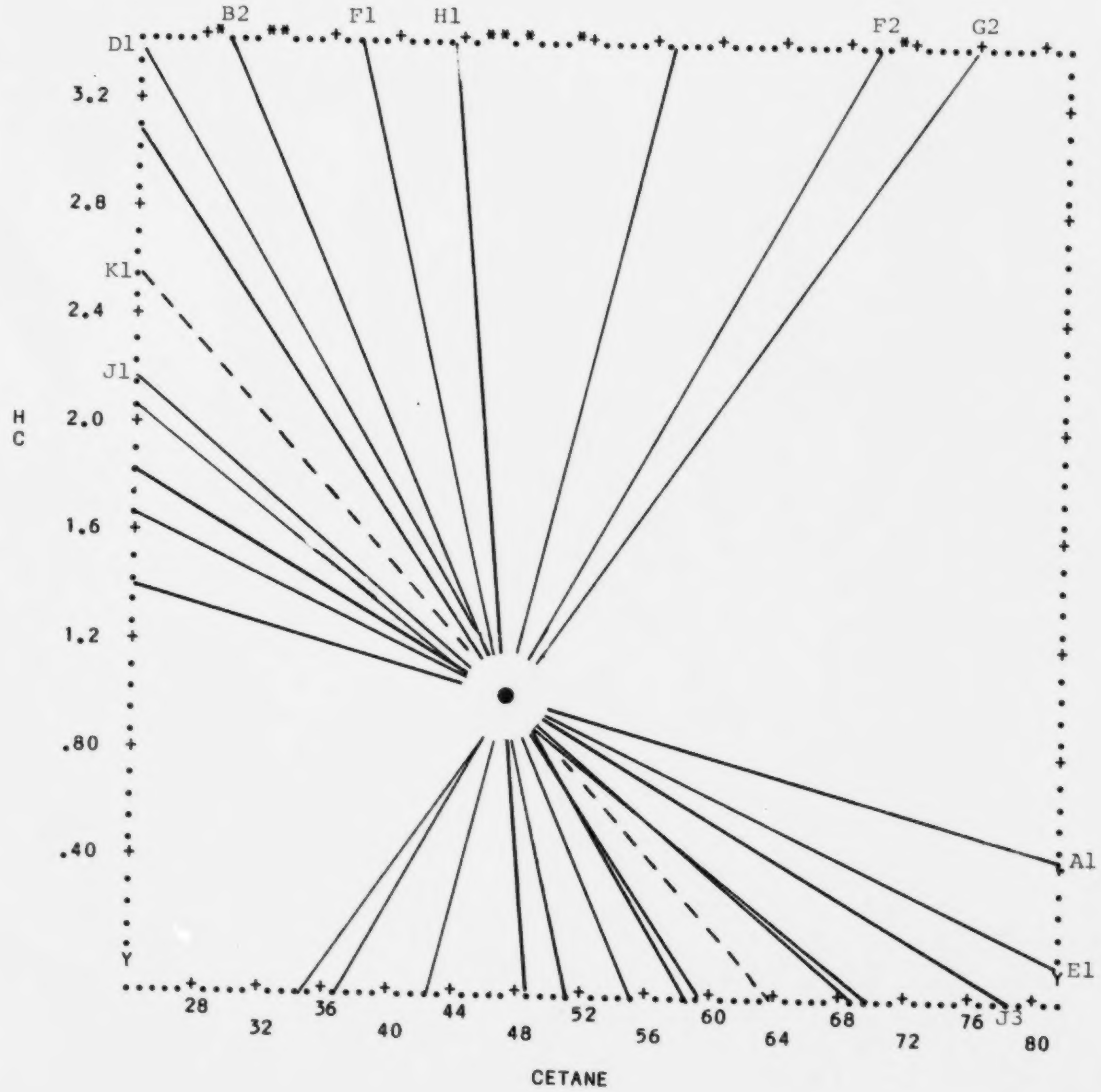
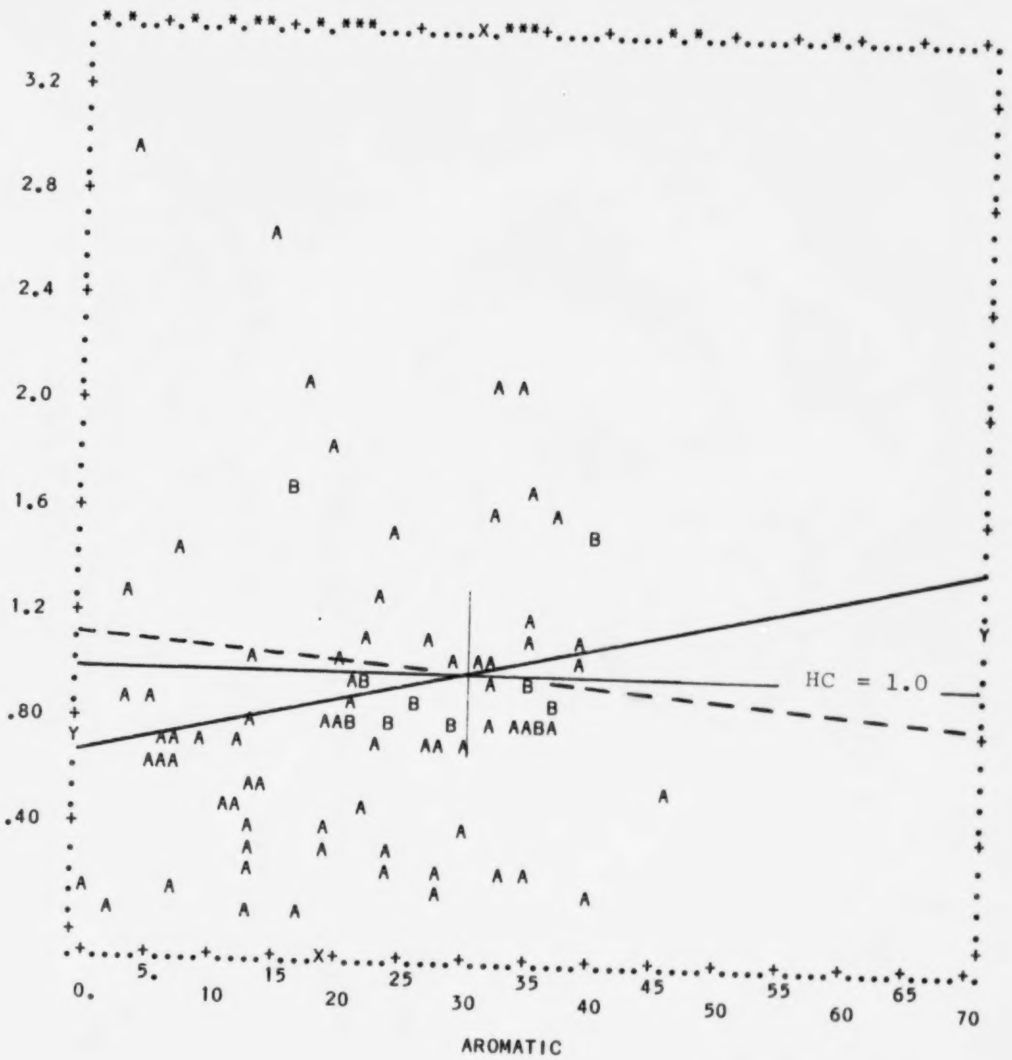


Figure 7. Normalized HC versus cetane by individual study.

TABLE 28. COMPARISON OF OBSERVED VERSUS PREDICTED HYDROCARBONS AS A FUNCTION OF FUEL CETANE USING PETROLEUM-BASED FUEL STUDY EQUATION AND ALTERNATE-SOURCE FUEL DATA

Cetane No.	Observed HC	"J" Predicted HC	"K" (Observed-Predicted)^2	"K"/"J"
50	0.9309	0.8723	0.0034	0.0039
49	0.9309	0.9730	0.0003	0.0003
45	1.1411	1.1957	0.0030	0.0025
42	1.1712	1.3897	0.0477	0.0343
35	2.0402	1.8424	0.0399	0.0217
38	1.8018	1.6483	0.0235	0.0143
44	0.9910	1.2603	0.0725	0.0575
45	1.0210	1.1957	0.0305	0.0255
50	0.9610	0.8723	0.0079	0.0091
42	1.0811	1.3897	0.0952	0.0685

$$X^2 = \Sigma \frac{"K"}{"J"} = 0.2376$$



Petroleum
Solid Line

```
N=   83
COR= .141

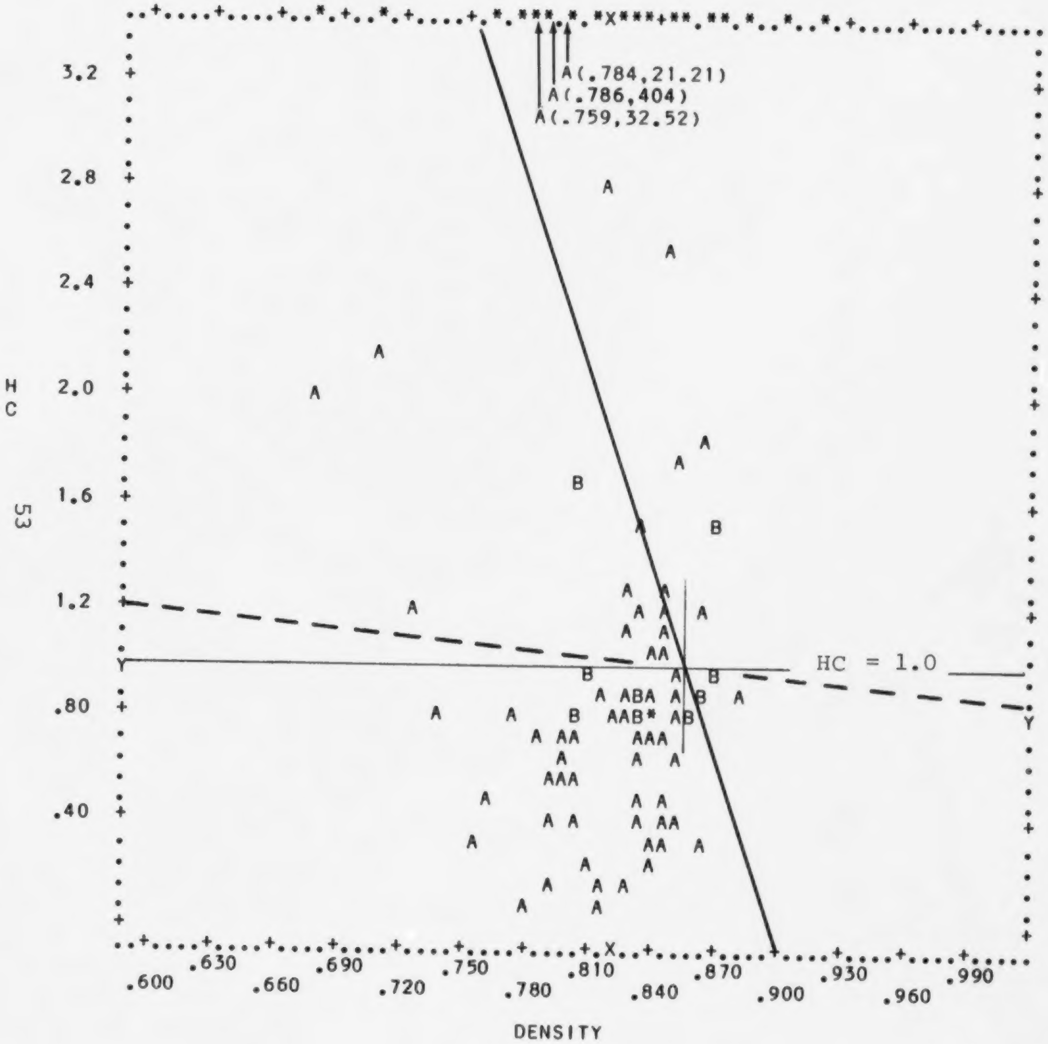
     MEAN      ST.DEV.     REGRESSION LINE          RES.MS.
X    21.430    11.289    X= 2.7817*Y+ 18.968        126.46
Y    .88527    .57197    Y= .00714*X+ .73224        .32461
```

Alternate
Dashed Line

```
N=   10
COR=-.086

     MEAN      ST.DEV.     REGRESSION LINE          RES.MS.
X    28.590    8.0524    X=-2.1452*Y+ 30.746        72.401
Y    1.0050    .32442    Y=-.00348*X+ 1.1046        .11752
```

Figure 8. Normalized HC versus aromatics.



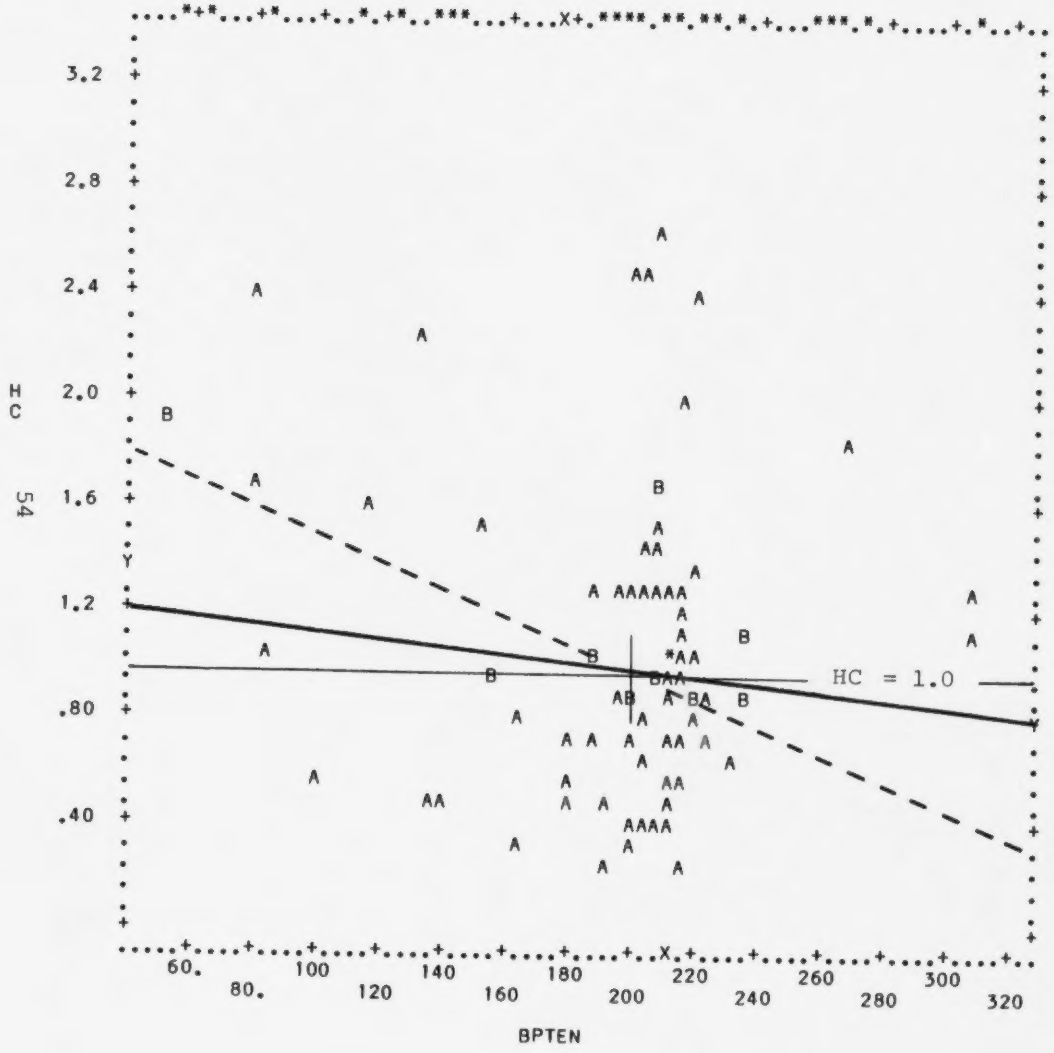
```
                          Petroleum
                          Solid Line
N=   86
COR=-.220

    MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   .81541    .03993   X=-.00209*Y+ .81939    .00154
Y   1.9074    4.2128   Y=-23.261*X+ 20.875    17.085
```

```
                          Alternate
N=   10                   Dashed Line
COR=-.056

    MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   .83770    .02546   X=-.00440*Y+ .84214    727E-6
Y   1.0100    .32604   Y=-.72142*X+ 1.6144    .11921
```

Figure 9. Normalized HC versus density.



Petroleum
Solid Line

```
N=   76
COR=-.077

     MEAN     ST.DEV.     REGRESSION LINE       RES.MS.
X   200.24    41.010   X=-5.5852*Y+ 206.08     1694.5
Y   1.0470    .56361   Y=-.00105*X+ 1.2583     .32005
```

Alternate
Dashed Line

```
N=   10
COR=-.680

     MEAN     ST.DEV.     REGRESSION LINE       RES.MS.
X   191.60    53.707   X=-100.19*Y+ 304.74     1744.6
Y   1.1292    .36451   Y=-.00462*X+ 2.0135     .08036
```

Figure 10. Normalized HC versus 10% boiling point.

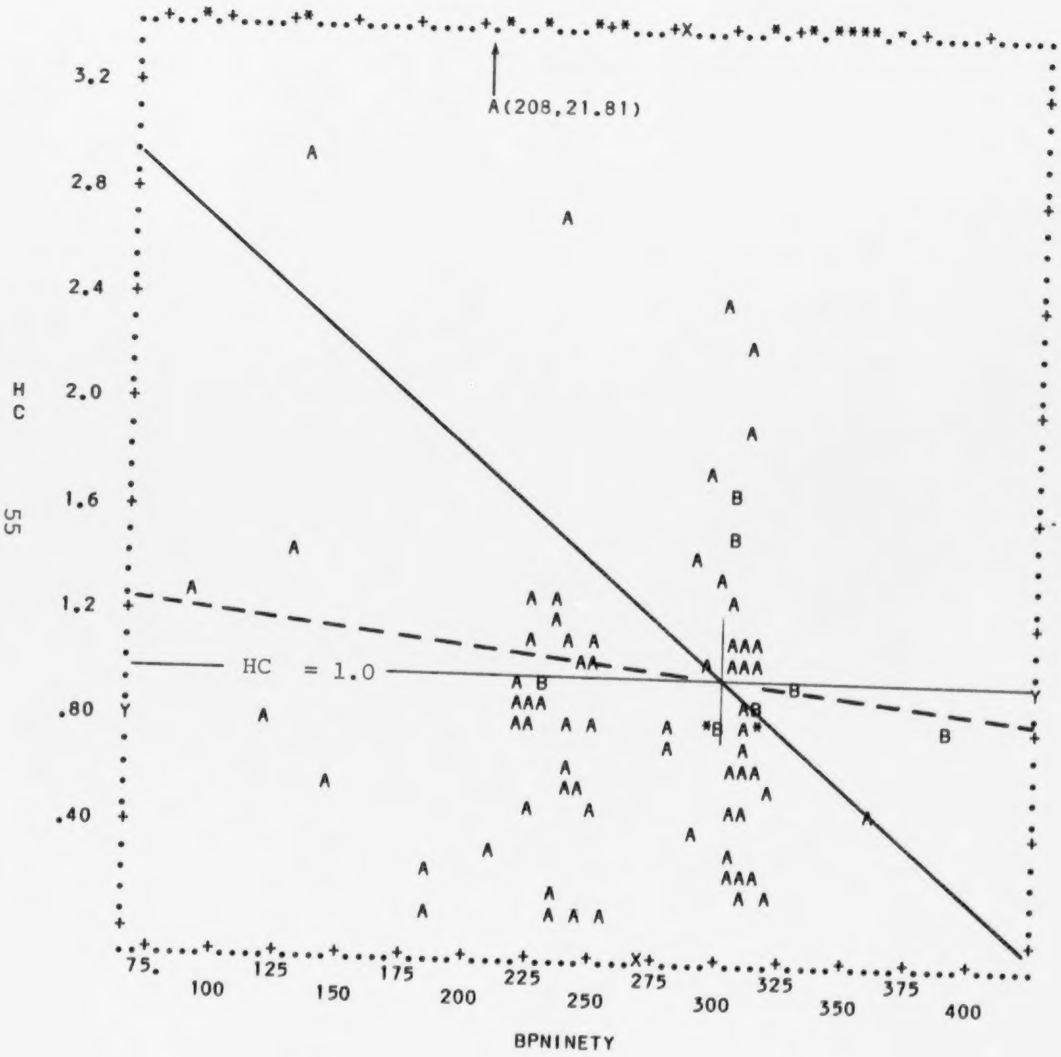


Figure 11. Normalized HC versus 90% boiling point.

```
                                   Petroleum
                                   Solid Line
N=   96
COR=-.160

  MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X 267.07    56.353    X=-4.0542*Y+ 271.82      3127.2
Y 1.1710    2.2251    Y=-.00632*X+ 2.8590      4.8754


                                   Alternate
N=   10                            Dashed Line
COR=-.141

  MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X 308.70    39.936    X=-17.543*Y+ 326.11      1758.7
Y .99259    .32042    Y=-.00113*X+ 1.3412      .11322
```

values for all the hydrocarbons-fuel property data pairs. The calculated "chi-square" values were compared to the $X^2_{.95}$ percentile value to determine if substitution of alternate source fuel properties into petroleum-based fuel prediction equations yielded statistically different results than emissions observed while using alternate-soruce fuels.

TABLE 29. HYDROCARBON DATA PAIRS GOODNESS-OF-FIT

Data Pair	Calculated "Chi-Square"	Petroleum vs. Alternate Statistically Different
HC - Cetane	0.238	No
HC - Aromatics	1.19	No
HC - Density	3.53	No
HC - 10% Boiling Point	0.920	No
HC - 90% Boiling Point	1.63	No

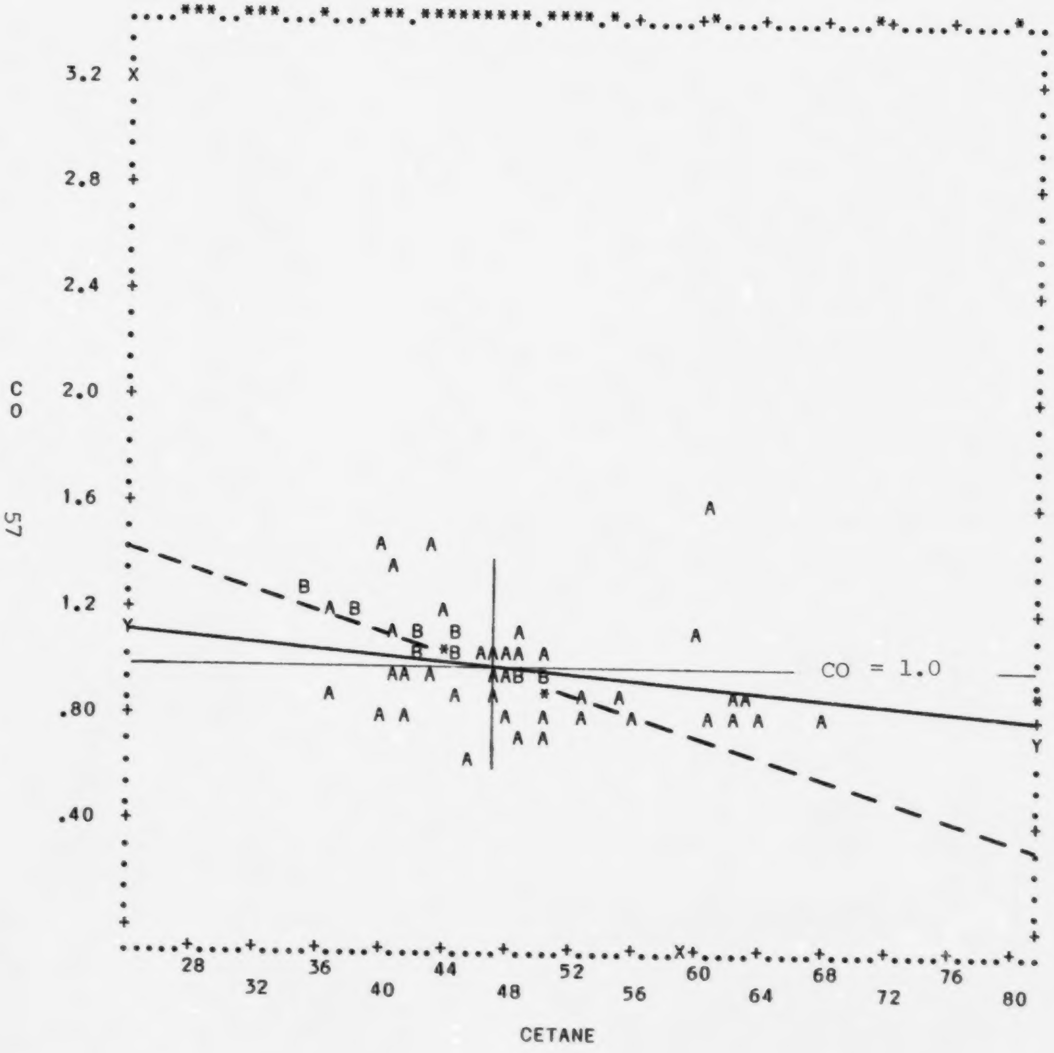
In summary, the effects of fuel aromatic content, cetane number, density and 90 percent boiling point on hydrocarbon emissions were about the same, independent of the source (petroleum-based or alternate-source). Although goodness-of-fit indicated that the 10 percent boiling point affected HC regardless of the source, the plot of the individual study lines showed a wide variation of HC response to petroleum-based fuels. This wide variation does not allow for a clear trend to be interpreted. Figure 9 shows the petroleum-base fuel line forced to reach a few points off-scale. It appears that without these points, the petroleum-based fuel line would be similar to that of the alternate-source line.

2. Carbon Monoxide

Figures 12 through 14 present the carbon monoxide data as functions of cetane number, aromatics, and nitrogen. The individual line plots for each study (in common frame) are located in Appendix E. Table 30 presents the goodness-of-fit values for each of the CO-fuel property data pairs. As before, the "chi-square" values were compared in the $X^2_{.95}$ percentile to determine if statistical similarities existed. All the scattergrams and goodness-of-fit calculations indicate that the effects of fuel cetane number, aromatic content, and nitrogen content on CO emissions are similar regardless

TABLE 30. CO DATA PAIRS GOODNESS-OF-FIT

Data Pair	Calculated "Chi-Square"	Petroleum vs. Alternate Statistically Different
CO - Cetane	0.116	No
CO - Aromatics	0.117	No
CO - Nitrogen	0.061	No



Petroleum
Solid Line

```
N=   54
COR=-.200

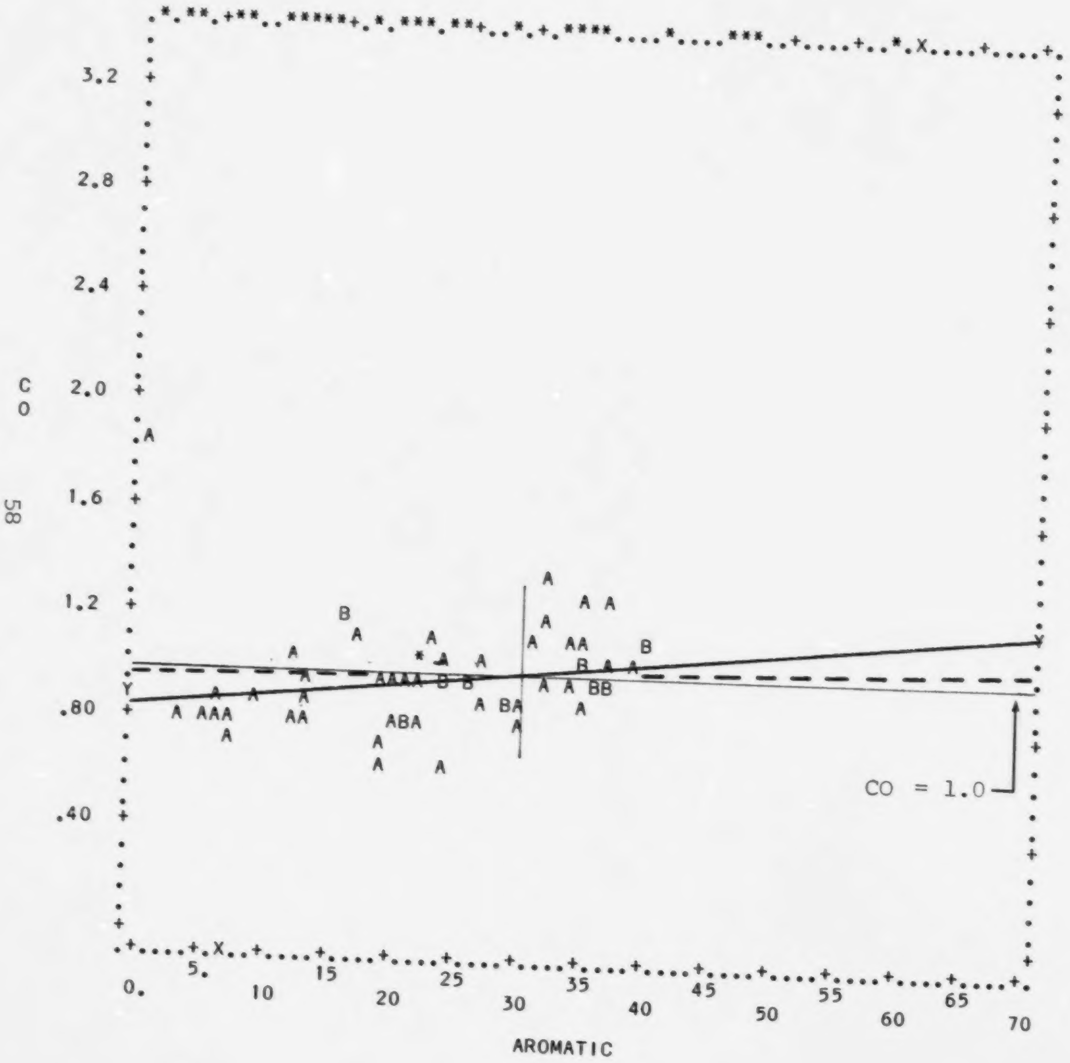
     MEAN      ST.DEV.     REGRESSION LINE      RES.MS.
X   48.815     7.1153   X=-7.4838*Y+ 56.042     49.541
Y   .96567     .18998   Y=-.00534*X+ 1.2261     .03532
```

Alternate
Dashed Line

```
N=   10
COR=-.922

     MEAN      ST.DEV.     REGRESSION LINE      RES.MS.
X   44.000     4.9889   X=-41.380*Y+ 87.911     4.1923
Y   1.0612     .11117   Y=-.02055*X+ 1.9653     .00208
```

Figure 12. Normalized CO versus cetane.



Petroleum
Solid Line

```
N=   56
COR= .272

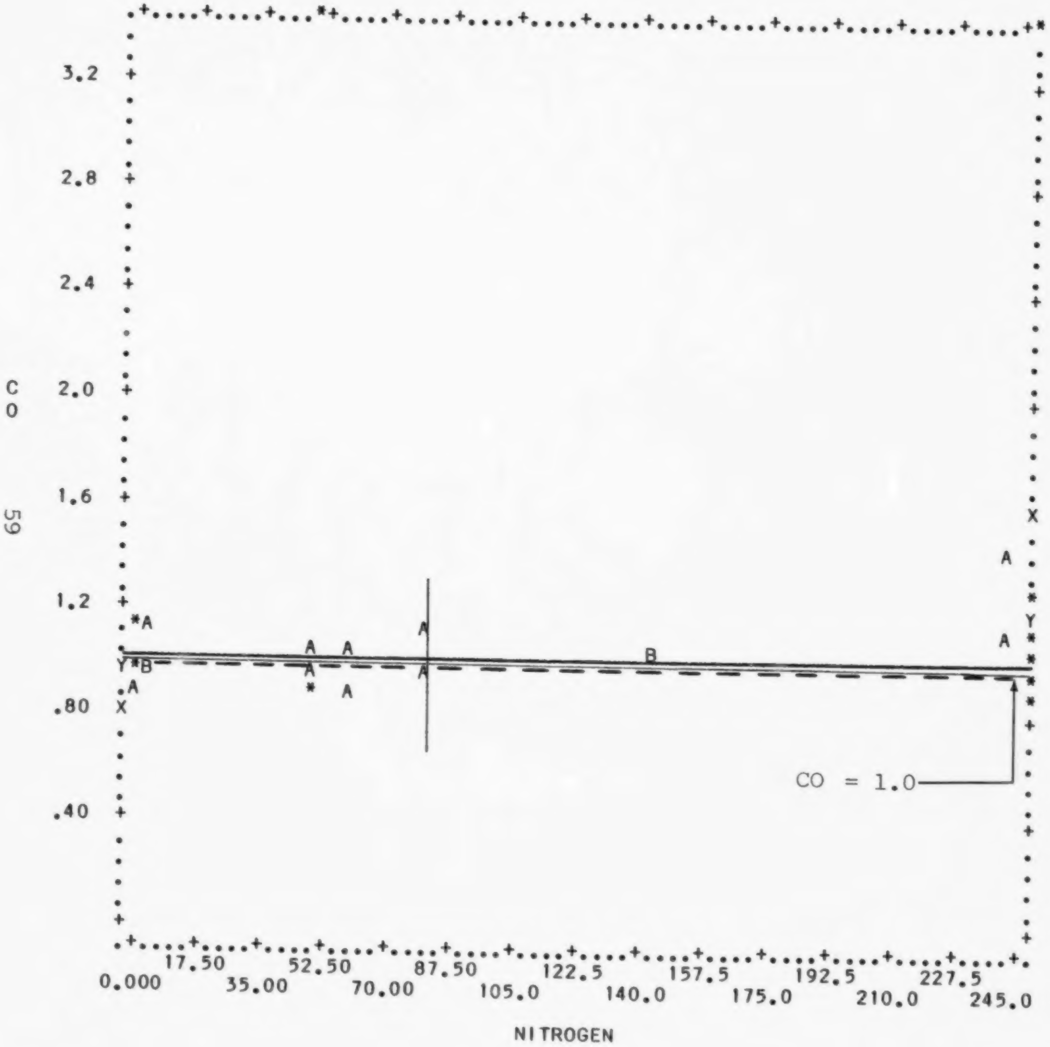
     MEAN     ST.DEV.     REGRESSION LINE       RES.MS.
X   21.979    10.717   X= 14.688*Y+ 7.9194      108.34
Y   .95719    .19825   Y= .00503*X+ .84671      .03708
```

Alternate
Dashed Line

```
N=   10
COR= .040

     MEAN     ST.DEV.     REGRESSION LINE       RES.MS.
X   28.590    8.0524   X= 3.0995*Y+ 25.493      72.828
Y   .99913    .10467   Y= 524E-6*X+ .98416      .01230
```

Fiugre 13. Normalized CO versus aromatics.



```
                    Petroluem
                    Solid Line
N=   21
COR= .138

     MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   171.00    263.07   X= 245.15*Y-78.175      71458.
Y   1.0164    .14813   Y= 777E-7*X+ 1.0031     .02266


                    Alternate
N=   10             Dashed Line
COR= .656

     MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   604.40    742.46   X= 4422.9*Y-4042.4      353645
Y   1.0506    .11004   Y= 972E-7*X+ .99189     .00777
```

Figure 14. Normalized CO versus nitrogen.

of the fuel source.

3. Oxides of Nitrogen

The NO_x data as functions of aromatics, density, and 10 percent boiling point are shown in Figures 15 through 17. Appendix E contains the same data plotted as individual lines representing each study. Table 31 lists the goodness-of-fit values for each of the NO_x data pairs. Comparing the "chi-square" values in Table 31 to $X^2_{.95}$ (16.9) indicates that the effects of fuel aromatics, density, and 10 percent boiling point on NO_x emissions are similar regardless of the fuel source. Figure 16 shows a sharper slope for the alternate-source data than the petroleum data. This slope can be misleading in that the alternate-source data points do not exhibit a wide population dispersion and are located quite near the fuel density value to which the NO_x data were normalized.

TABLE 31. NO_x DATA PAIRS GOODNESS-OF-FIT

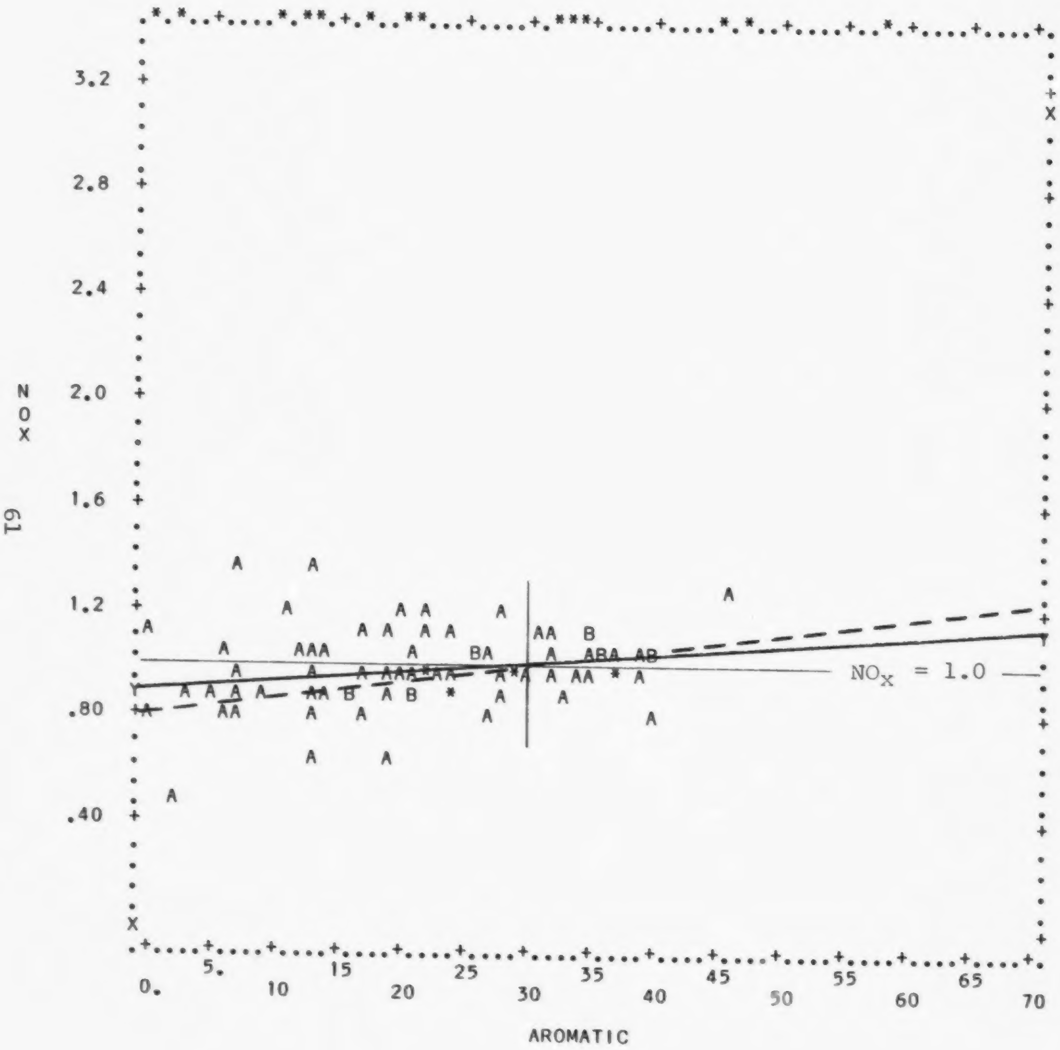
Data Pair	Calculated "Chi-Square"	Petroleum vs. Alternate Statistically Different
NO_x - Aromatics	0.045	No
NO_x - Density	0.062	No
NO_x - 10% Boiling Point	0.640	No

4. Particulate

Figures 18through 21 present particulate data as a function of fuel aromatics, 90 percent boiling point, density, and 10 percent boiling point. Individual regression lines representing each study, in common graphs, are located in Appendix E. Table 32 gives the goodness-of-fit values for each of the particulate-fuel property data pairs. Calculated "chi-squares" indicate that fuel aromatics, 90 percent boiling point, density, and 10 percent boiling point affect particulate emissions similarly for both petroleum-based fuels and alternate-source fuels. Although the calculated "chi-square" value for the 10 percent boiling point is the highest of all the particulate-fuel property data pairs (1.713), the slopes of the alternate-source study and the

TABLE 32. PARTICULATE DATA PAIRS GOODNESS-OF-FIT

Data Pair	Calculated "Chi-Square"	Petroleum vs. Alternate Statistically Different
Particulate - Aromatics	0.133	No
Particulate - 10% Boiling Point	0.421	No
Particulate - Density	0.127	No
Particulate - 90% Boiling Point	1.713	No



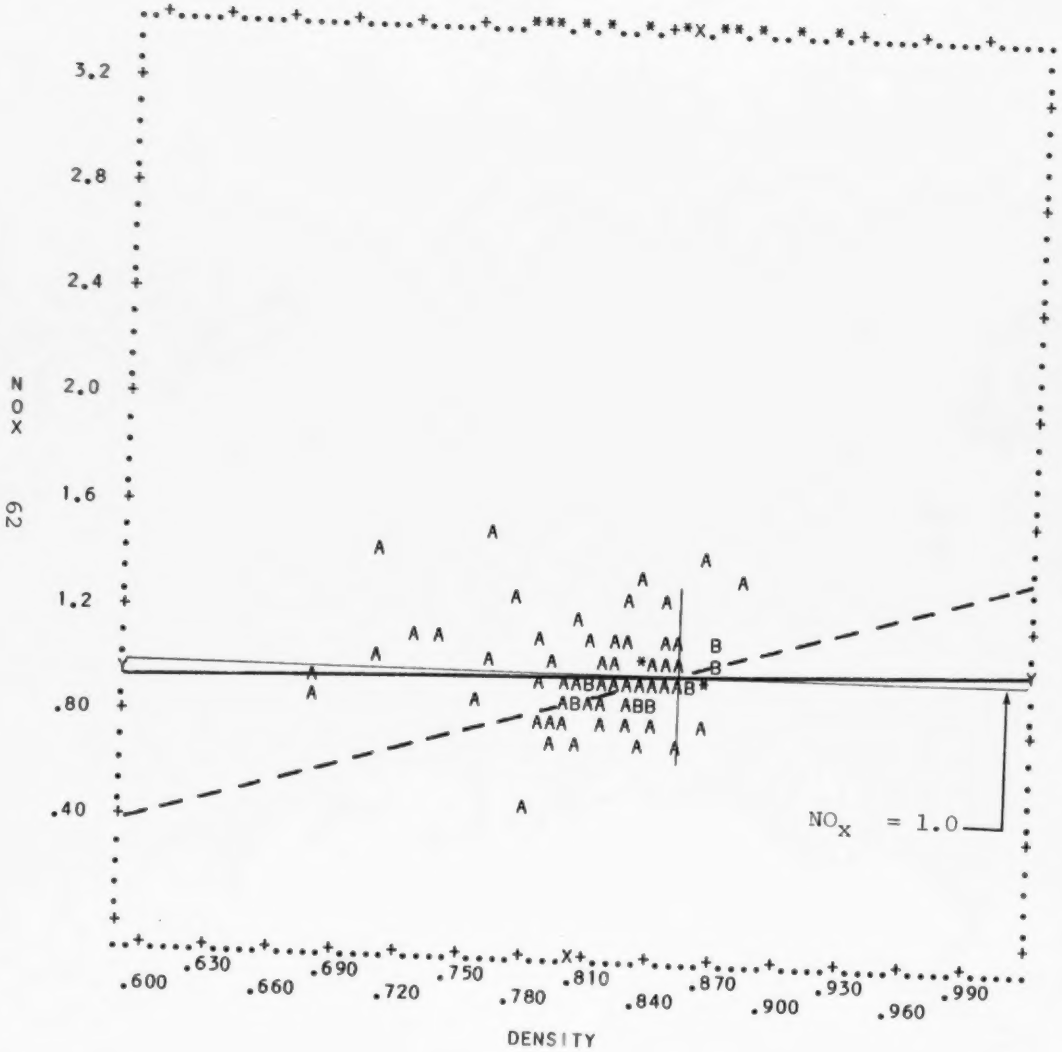
```
                Petroleum
                Solid Line
N=   87
COR= .256

     MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X    20.895    11.396    X= 21.231*Y+ .21010     122.79
Y    .97428    .13739    Y= .00309*X+ .90980     .01785
```

```
                Alternate
                Dashed Line
N=   10
COR= .648

     MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X    28.590    8.0524    X= 62.390*Y-33.192      42.279
Y    .99025    .08368    Y= .00674*X+ .79760     .00457
```

Figure 15. Normalized NO_X versus aromatics.



Petroleum
Solid Line

```
N=  87
COR= .043

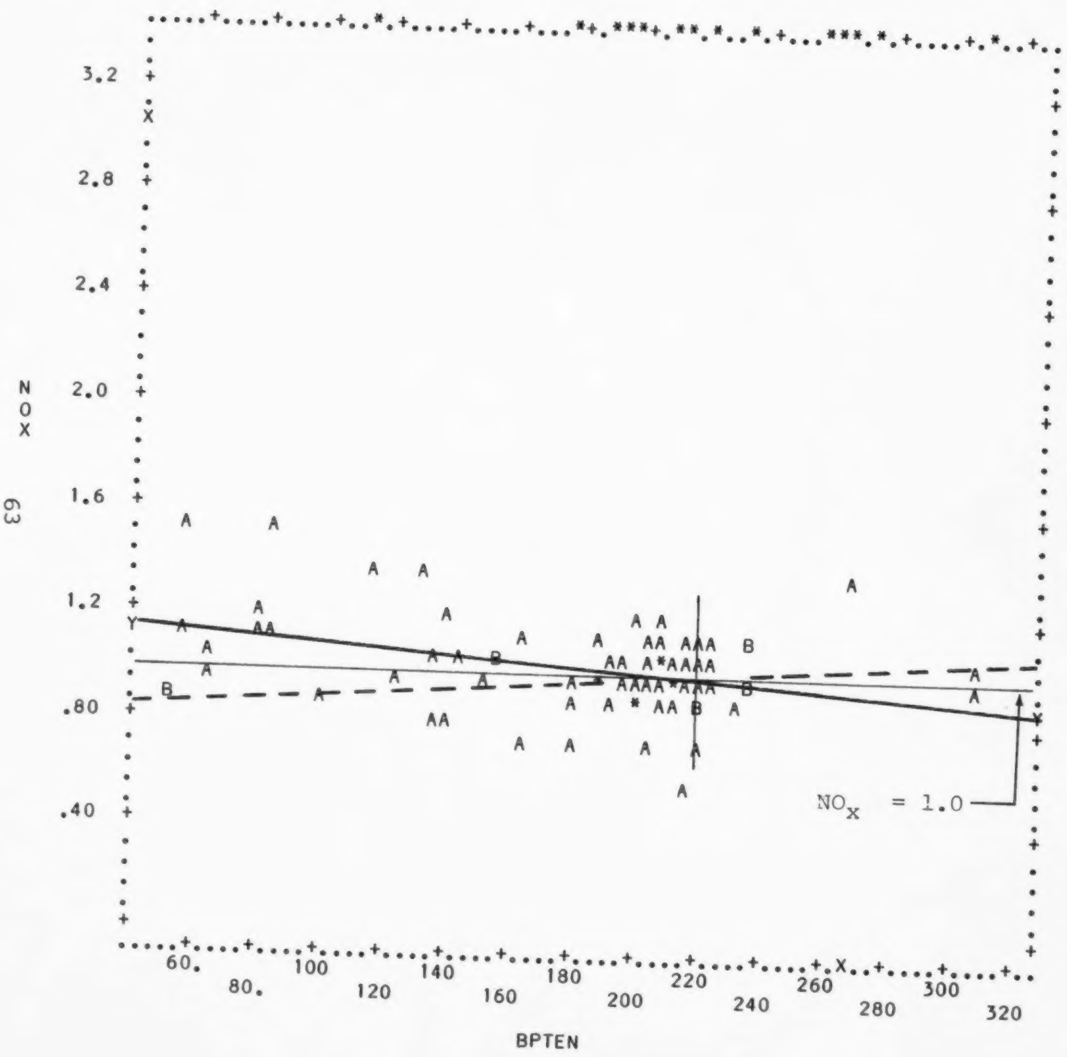
   MEAN     ST.DEV.    REGRESSION LINE      RES.MS.
X  .81523   .03974  X= .00988*Y+ .80542     .00159
Y  .99281   .17358  Y= .18852*X+ .83913     .03043
```

Alternate
Dashed Line

```
N=  10
COR= .739

   MEAN     ST.DEV.    REGRESSION LINE      RES.MS.
X  .83770   .02546  X= .22911*Y+ .61516     331E-6
Y  .97132   .08210  Y= 2.3831*X-1.0250      .00344
```

Figure 16. Normalized NO$_x$ versus density.



Petroleum
Solid Line

```
N=   87
COR=-.246

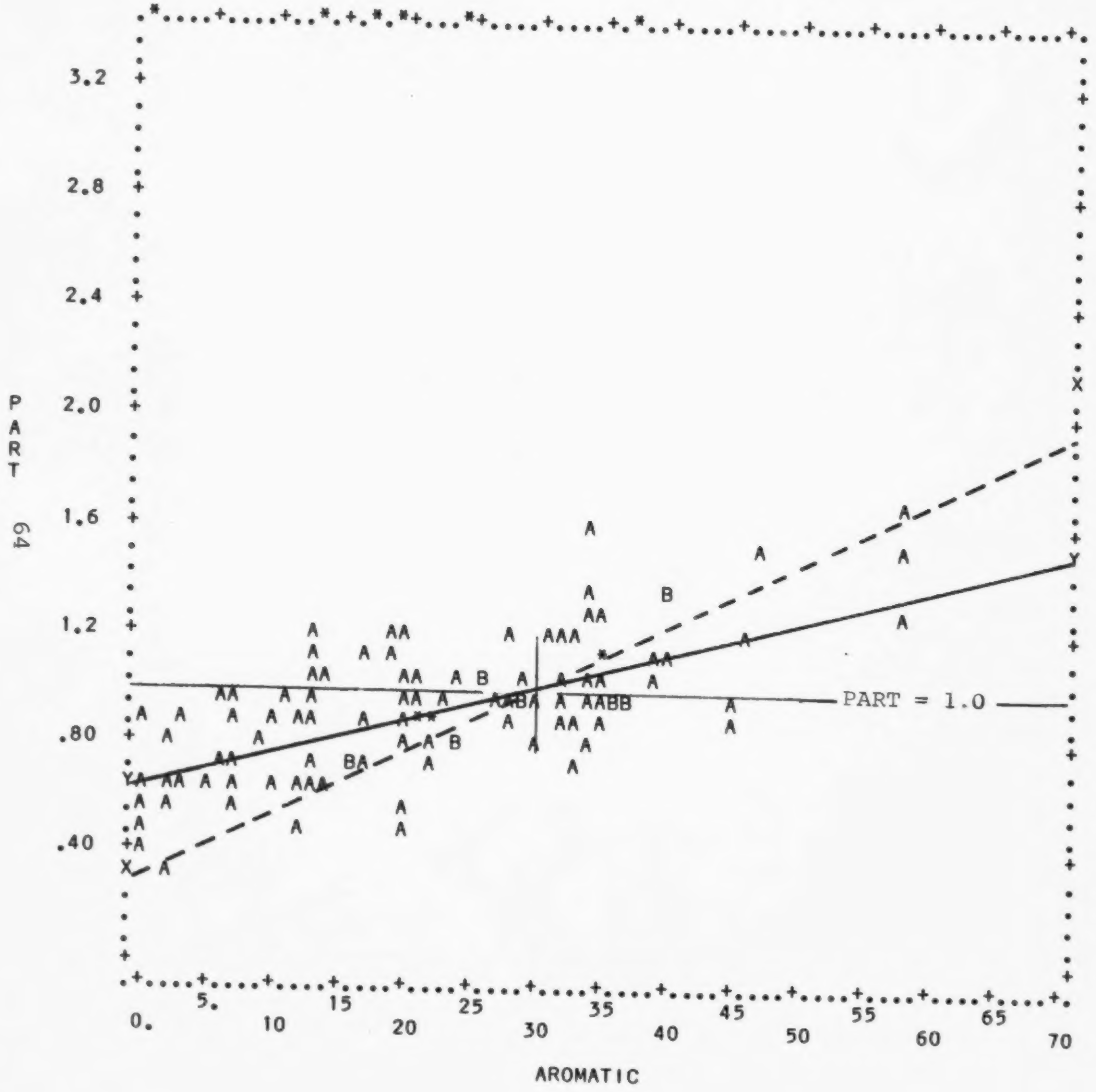
    MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   189.66   51.422   X=-80.717*Y+ 270.78     2513.6
Y   1.0050   .15664   Y=-749E-6*X+ 1.1471     .02332
```

Alternate
Dashed Line

```
N=   10
COR= .315

    MEAN     ST.DEV.     REGRESSION LINE      RES.MS.
X   191.60   53.707   X= 203.01*Y-8.5940      2923.1
Y   .98614   .08333   Y= 489E-6*X+ .89250     .00704
```

Figure 17. Normalized NO$_x$ versus 10% boiling point.



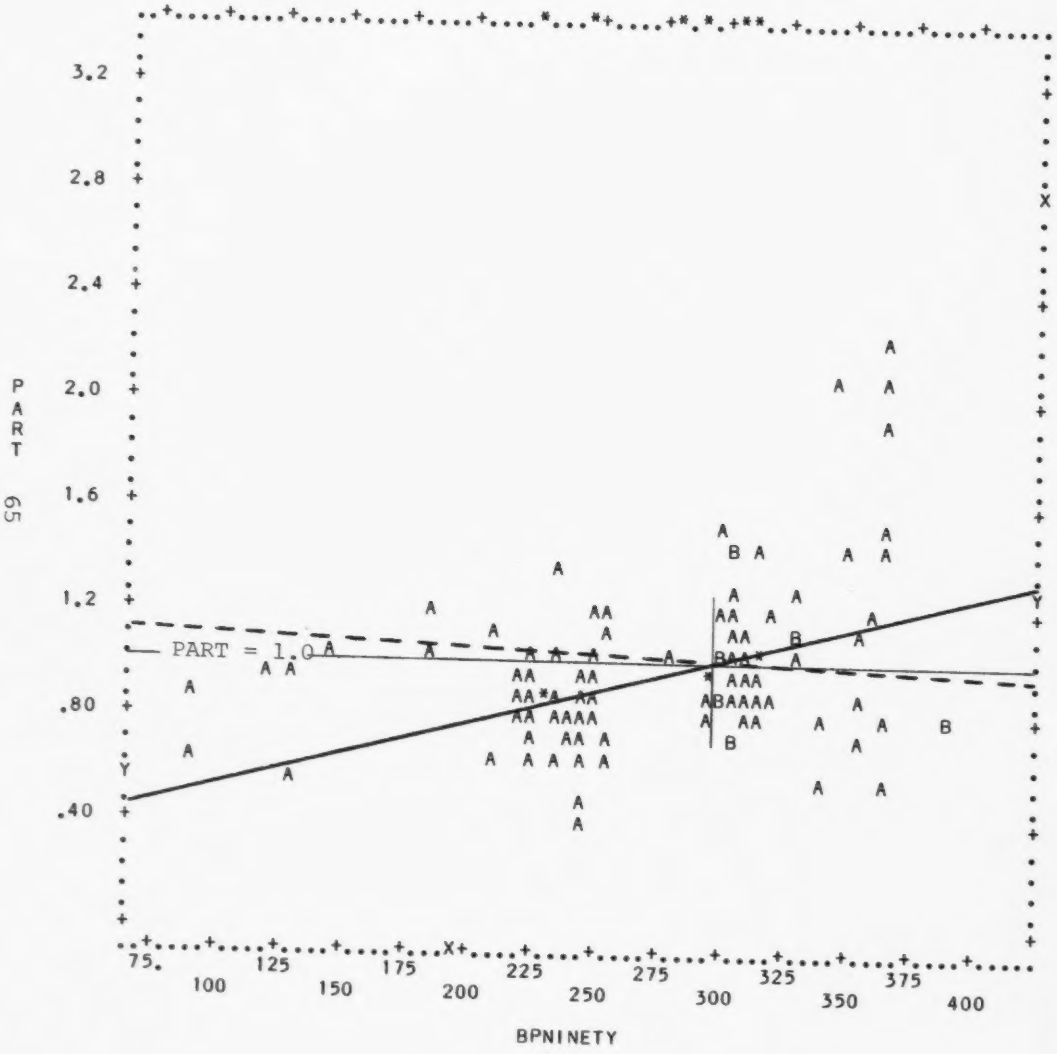
```
                         Petroleum
                         Solid Line
N=  112
COR= .701

     MEAN     ST.DEV.     REGRESSION LINE        RES.MS.
X   21.012    14.112   X= 38.669*Y-13.856        102.33
Y   .90169    .25567   Y= .01269*X+ .63500       .03359
```

```
                         Alternate
                         Dashed Line
N=   10
COR= .803

     MEAN     ST.DEV.     REGRESSION LINE        RES.MS.
X   28.590    8.0524   X= 34.579*Y-5.1281        25.902
Y   .97509    .18701   Y= .01865*X+ .44188       .01397
```

Figure 18. Normalized particulate versus aromatics.



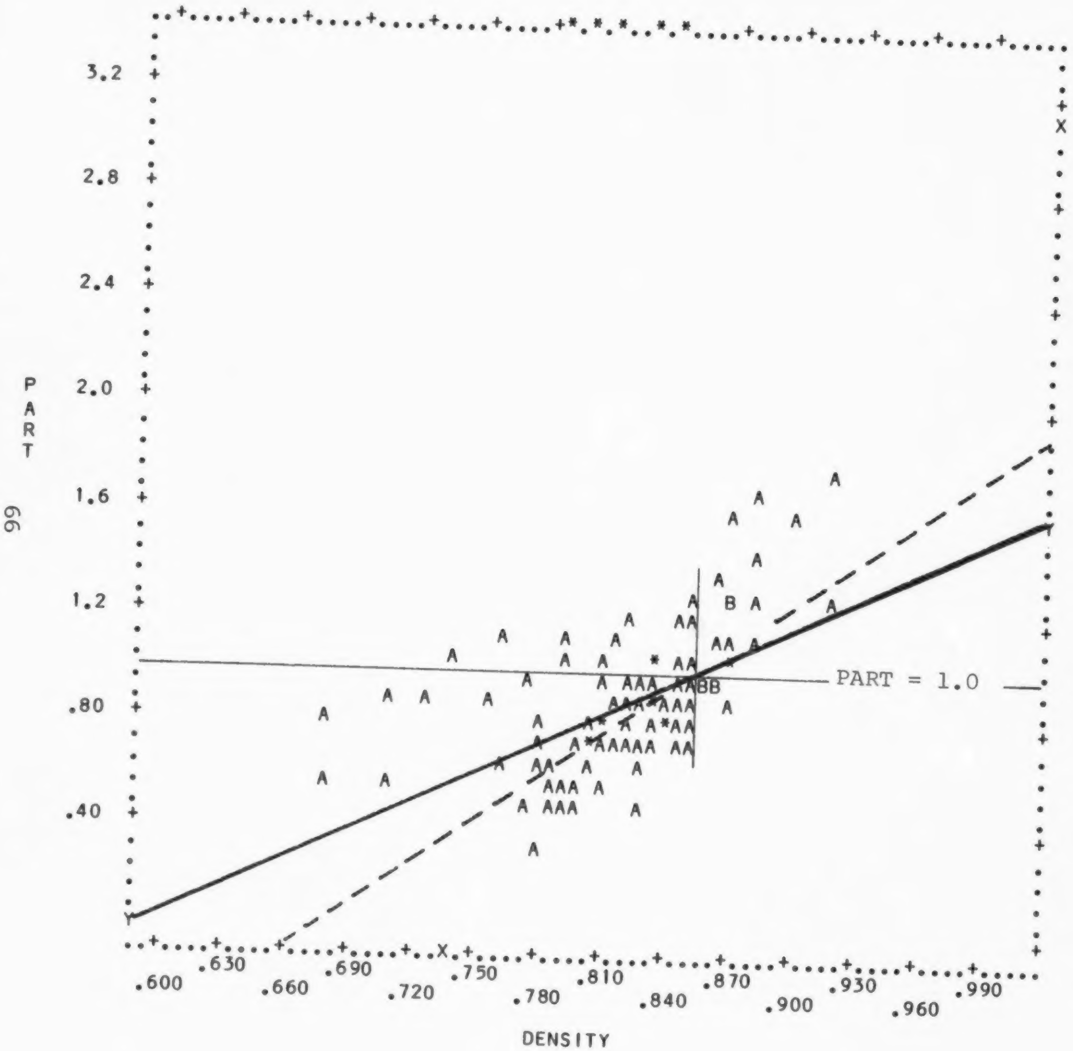
```
N=  112          Petroleum
COR= .432        Solid Line

    MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X   276.96    61.310    X= 82.100*Y+ 195.17     3086.3
Y   .99628    .32235    Y= .00227*X+ .36770     .08532


N=   10          Alternate
COR=-.087        Dashed Line

    MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X   308.70    39.936    X=-18.213*Y+ 326.91     1780.5
Y   .99965    .19170    Y=-420E-6*X+ 1.1292     .04103
```

Figure 19. Normalized particulate versus 90% boiling point.



Petroleum
Solid Line

```
N=  112
COR= .565

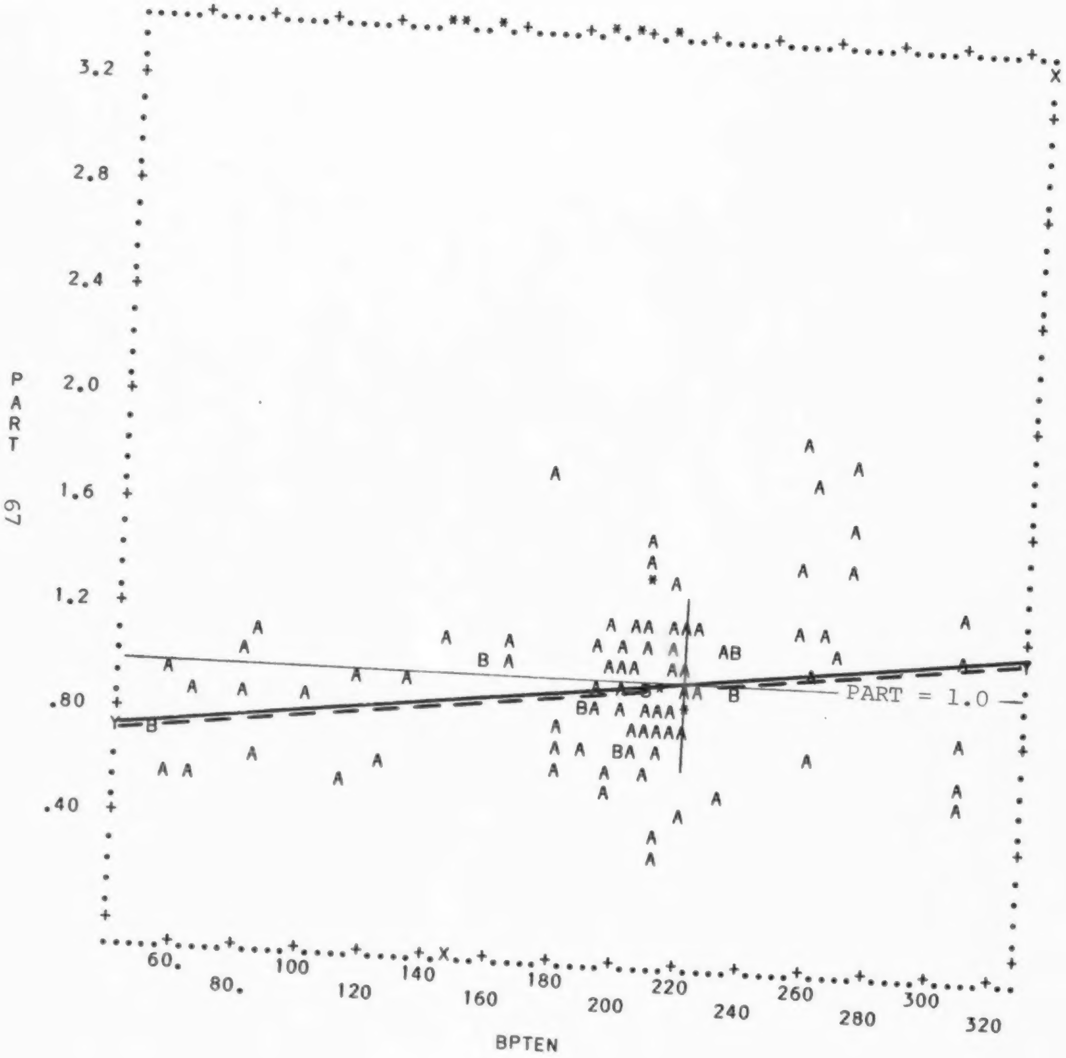
     MEAN     ST.DEV.      REGRESSION LINE       RES.MS.
X   .82167    .04249   X= .08736*Y+ .74464      .00124
Y   .88174    .27503   Y= 3.6602*X-2.1258       .05192
```

Alternate
Dashed Line

```
N=   10
COR= .806

     MEAN     ST.DEV.      REGRESSION LINE       RES.MS.
X   .83770    .02546   X= .11511*Y+ .73072     256E-6
Y   .92943    .17823   Y= 5.6425*X-3.7973      .01253
```

Figure 20. Normalized particulate versus density.



```
N=  112          Petroleum
COR= .273        Solid Line

     MEAN     ST.DEV.     REGRESSION LINE         RES.MS.
X   203.20    52.199   X= 50.185*Y+ 154.81        2544.8
Y   .96412    .28379   Y= .00148*X+ .66271        .07522
```

```
                 Alternate
N=   10          Dashed Line
COR= .449

     MEAN     ST.DEV.     REGRESSION LINE         RES.MS.
X   191.60    53.707   X= 132.13*Y+ 65.847        2590.7
Y   .95171    .18252   Y= .00153*X+ .65934        .02992
```

Fiugre 21. Normalized particulate versus 10% boiling point.

petroleum-based studies are almost identical (Figure 21). This apparent anomally is due to the poor fit of the regression lines caused by scattered data. The data was scattered similarly in both cases to yield similar slopes.

5. Unregulated Emissions

The remaining selected fuel property-exhaust emission data pairs are shown in Figures 22 through 28. Again, the individual regression lines representing each study in a common frame (for each fuel property-emission variable pair) are located in Appendix E. Table 33 shows the goodness-of-fit for each fuel property-exhaust emission data pair. Calculated "chi-square" values do not indicate any statistically different between petroleum-based and alternate-source fuel effects on the exhaust emissions listed in Table 33.

TABLE 33. UNREGULATED EMISSION DATA PAIRS GOODNESS-OF-FIT

Data Pair	Calculated "Chi-Square"	Petroleum vs. Alternate Statistically Different
Fuel Consumption - Olefins	0.033	No
Fuel Consumption - Density	0.012	No
BaP - Nitrogen	1.96	No
BaP - Aromatics	2.25	No
Aldehyde - Aromatics	3.65	No
Solubles - Cetane	1.45	No
Solubles - Nitrogen	0.482	No

F. Additional Comments

In many cases, the scattergrams of the fuel property-exhaust emission data pairs did not visually support the trends determined by goodness-of-fit calculations. It should be noted that all the scattergrams contained regression lines representing both petroleum-based fuels and alternate-source fuels, regardless of the bivariate correlation coefficient values. Bivariate correlation coefficients less than 0.7 are not considered to represent a good fit of the data. In most cases, the coefficients were <0.7. Therefore, the lines themselves may be misleading. A detailed statistical analysis would have included an error band to show the range within which the lines could have fallen. As used in this study, goodness-of-fit does not imply good linear fit of the ata. In the case of this study, the goodness-of-fit shows that petroleum-based fuel data yield prediction equations which, when used in conjunction with alternate-soruce data, results in a scatter of predicted results that are statistically similar to the scattered results observed.

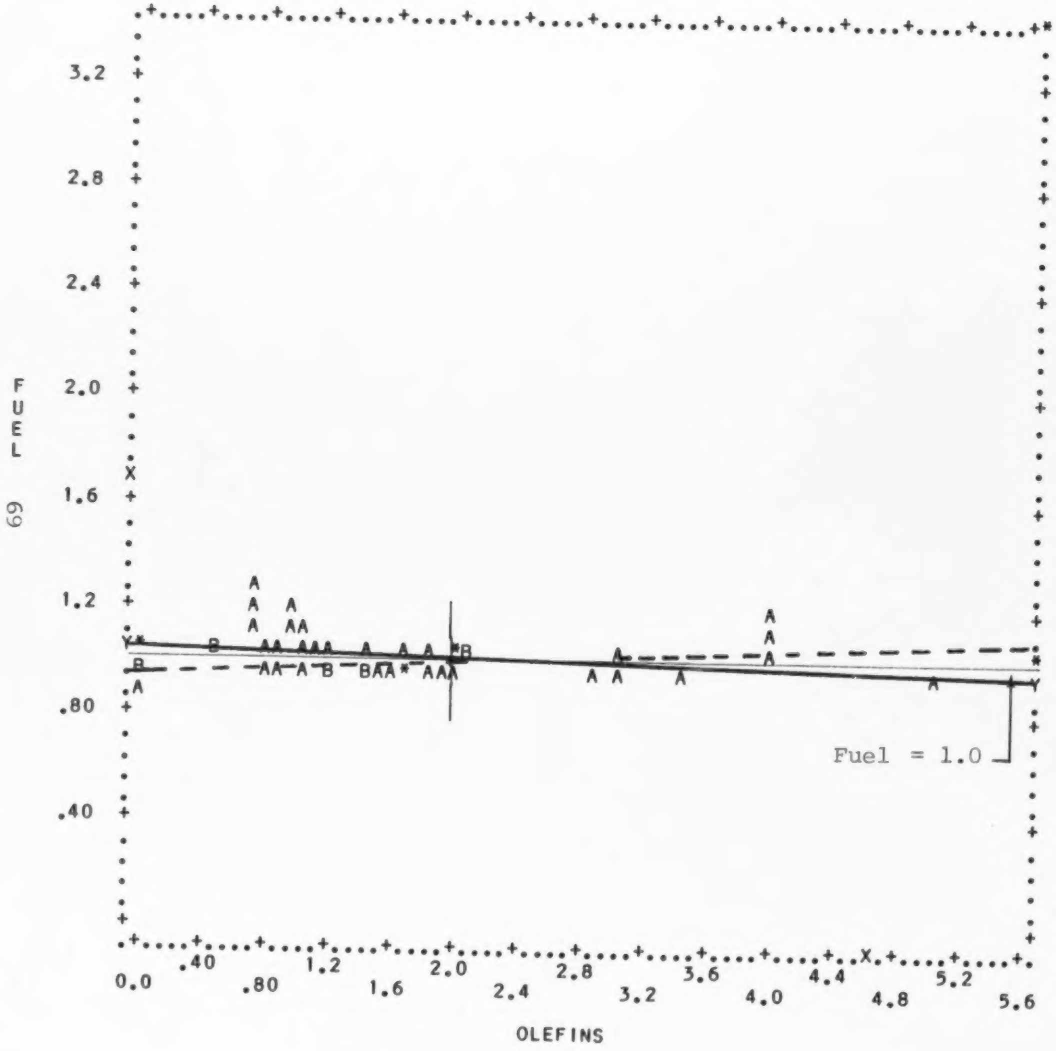


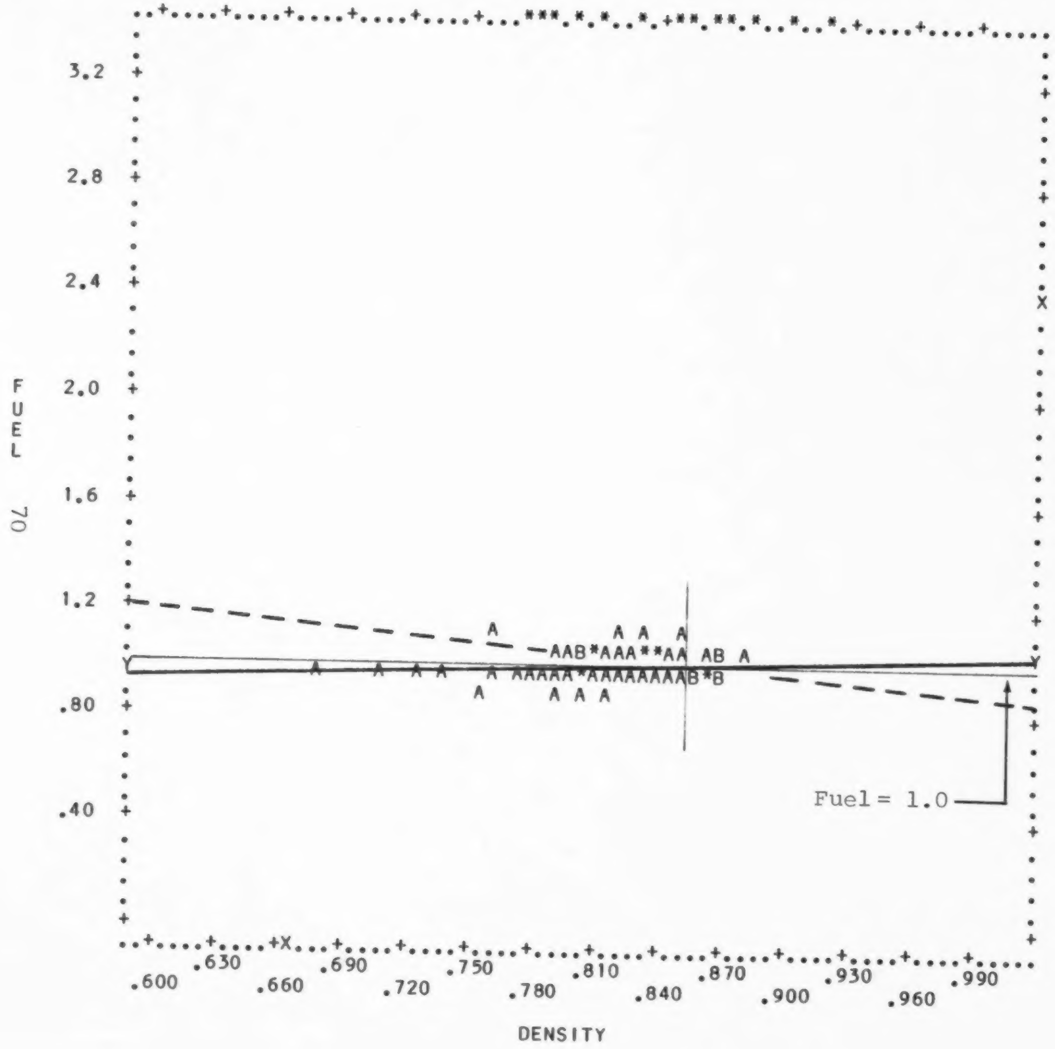
Figure 22. Normalized fuel versus olefins.

```
                              Petroleum
N=   69                       Solid Line
COR=-.238

      MEAN     ST.DEV.     REGRESSION LINE     RES.MS.
X    1.8116    1.1309   X=-3.5767*Y+ 5.4825    1.2244
Y    1.0263    .07529   Y=-.01585*X+ 1.0551    .00543


                              Alternate
N=   10                       Dashed Line
COR= .237

      MEAN     ST.DEV.     REGRESSION LINE     RES.MS.
X    1.0100    .82926   X= 6.3767*Y-5.3105     .73005
Y    .99119    .03086   Y= .00883*X+ .98227    .00101
```



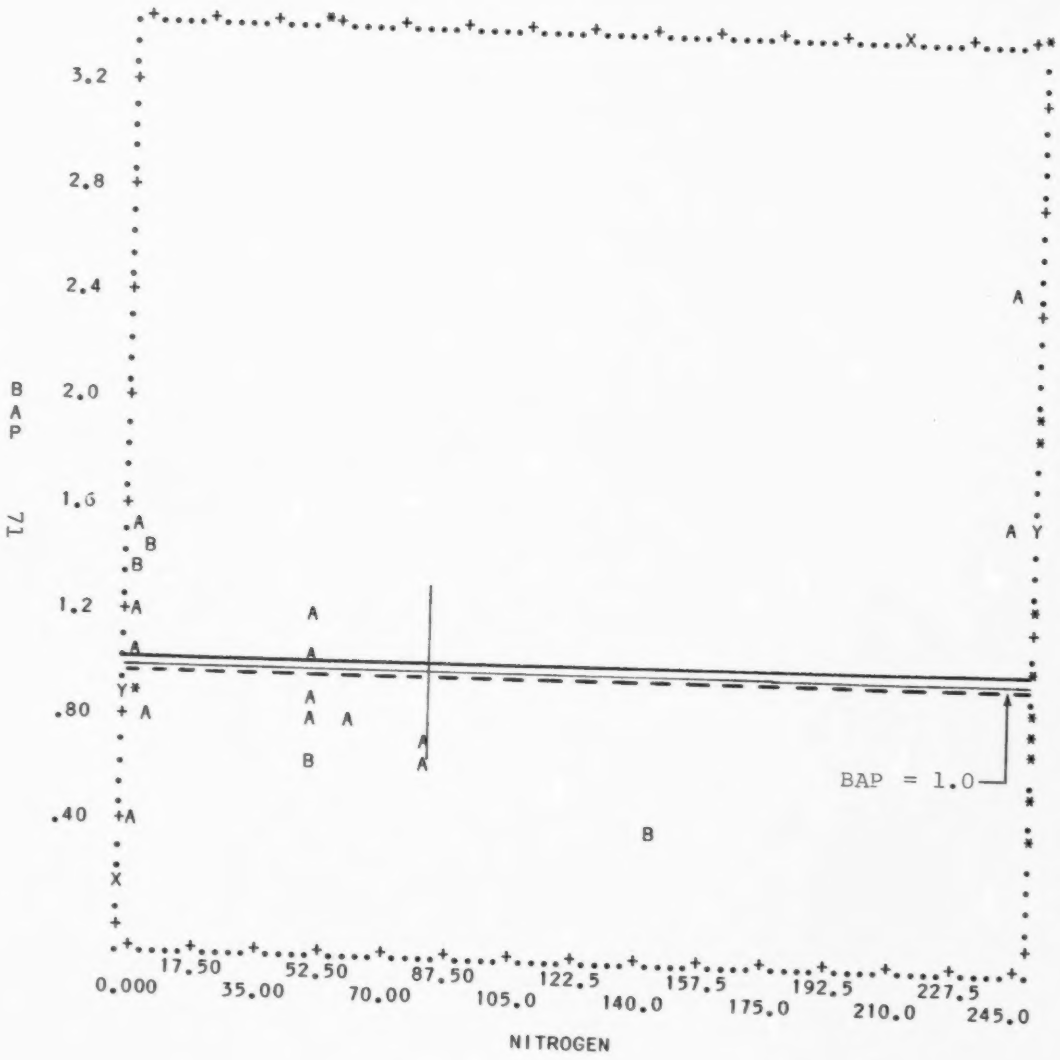
```
                                    Petroleum
                                    Solid Line
N=   85
COR= .195

     MEAN      ST.DEV.      REGRESSION LINE      RES.MS.
X    .81565    .04006    X= .15468*Y+ .66181     .00156
Y    .99455    .05062    Y= .24700*X+ .79309     .00249


                                    Alternate
                                    Dashed Line
N=   10
COR=-.621

     MEAN      ST.DEV.      REGRESSION LINE      RES.MS.
X    .83770    .02546    X=-.50251*Y+ 1.3450     448E-6
Y    1.0094    .03144    Y=-.76657*X+ 1.6516     684E-6
```

Figure 23. Normalized fuel versus density.



Petroleum
Solid Line

```
N=   21
COR= .077

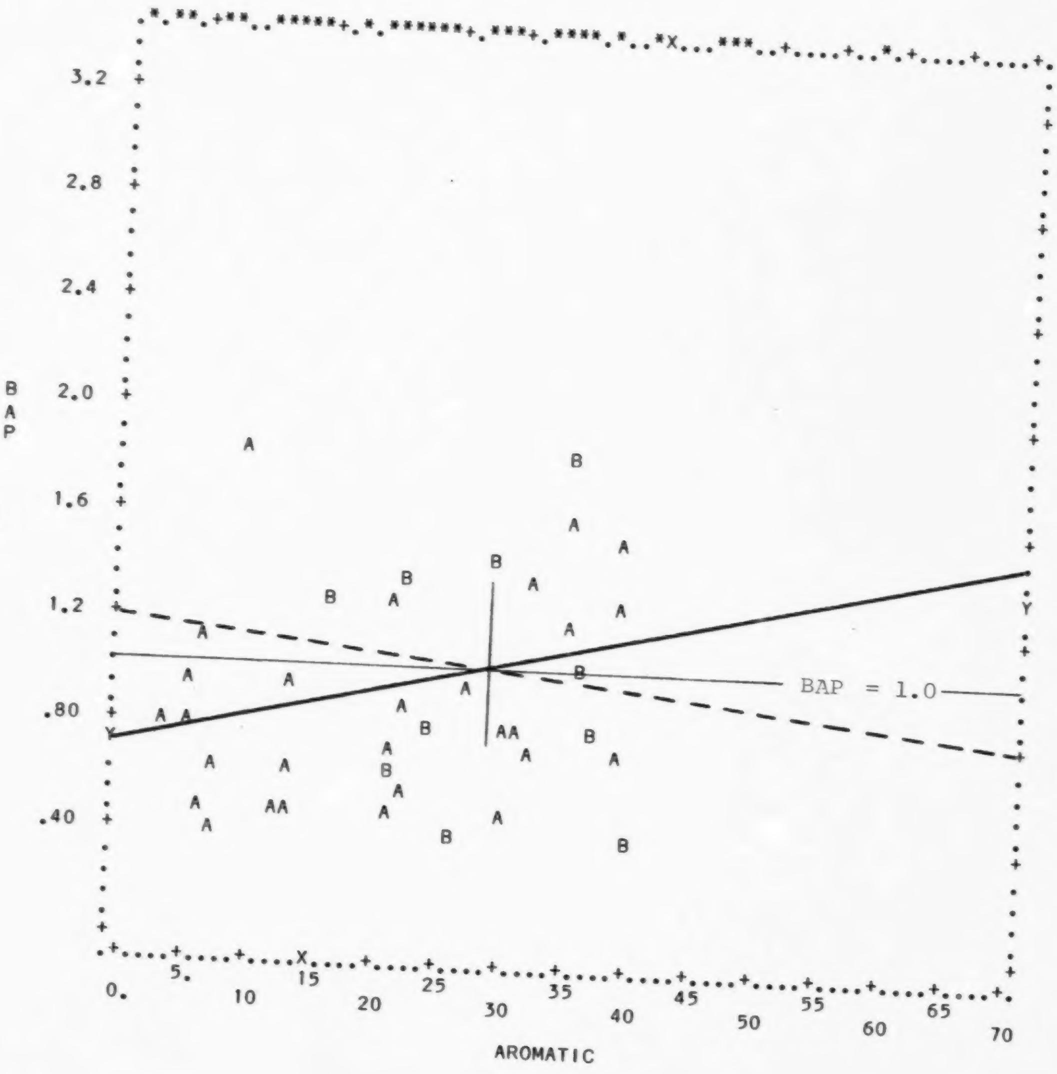
     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X    171.00    263.07    X= 40.591*Y+ 128.59      72410.
Y    1.0448    .50174    Y= 148E-6*X+ 1.0195      .26341
```

Alternate
Dashed Line

```
N=   10
COR= .068

     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X    604.40    742.46    X= 103.02*Y+ 498.95      617273
Y    1.0236    .49078    Y= 450E-7*X+ .99640      .26972
```

Figure 24. Normalized BaP versus nitrogen.



Petroleum
Solid Line

```
N=   29
COR= .327

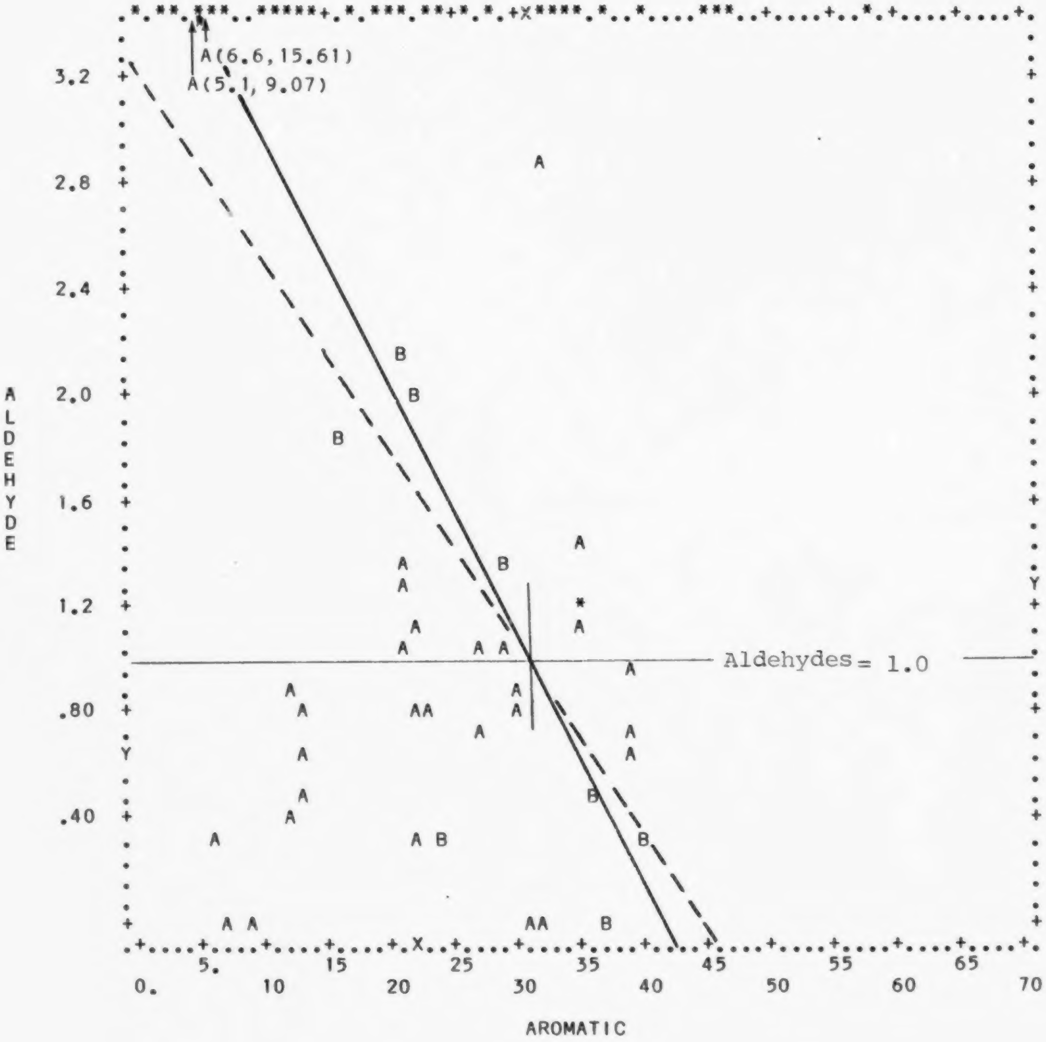
     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X   20.162     12.020   X= 10.271*Y+ 11.060      133.83
Y   .88624     .38263   Y= .01041*X+ .67642      .13560
```

Alternate
Dashed Line

```
N=   10
COR=-.081

     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X   28.590     8.0524   X=-1.3445*Y+ 29.944      72.472
Y   1.0068     .48273   Y=-.00483*X+ 1.1450      .26045
```

Figure 25. Normalized BaP versus aromatics.



Petroleum
Solid Line

```
N=   34
COR=-.398

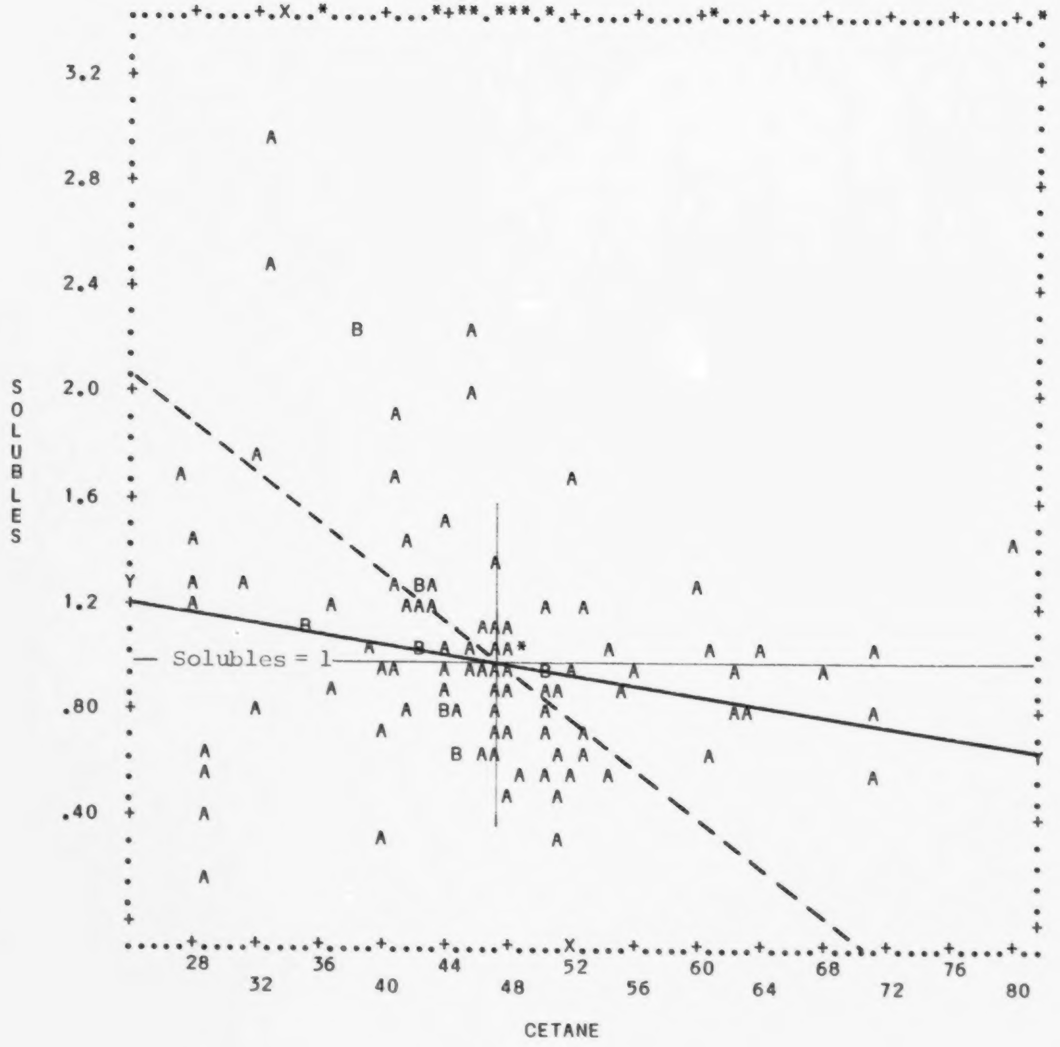
     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X   21.176     11.500   X=-1.4345*Y+ 23.795      114.73
Y    1.8256     3.1943  Y=-.11068*X+ 4.1694        8.8519
```

Alternate
Dashed Line

```
N=    9
COR=-.748

     MEAN      ST.DEV.     REGRESSION LINE        RES.MS.
X   28.933     8.4629   X=-7.6660*Y+ 37.197       36.067
Y    1.0779     .82565  Y=-.07297*X+ 3.1891        .34329
```

Figure 26. Normalized aldehyde versus aromatics.



Petroleum
Solid Line

```
N=  105
COR=-.219

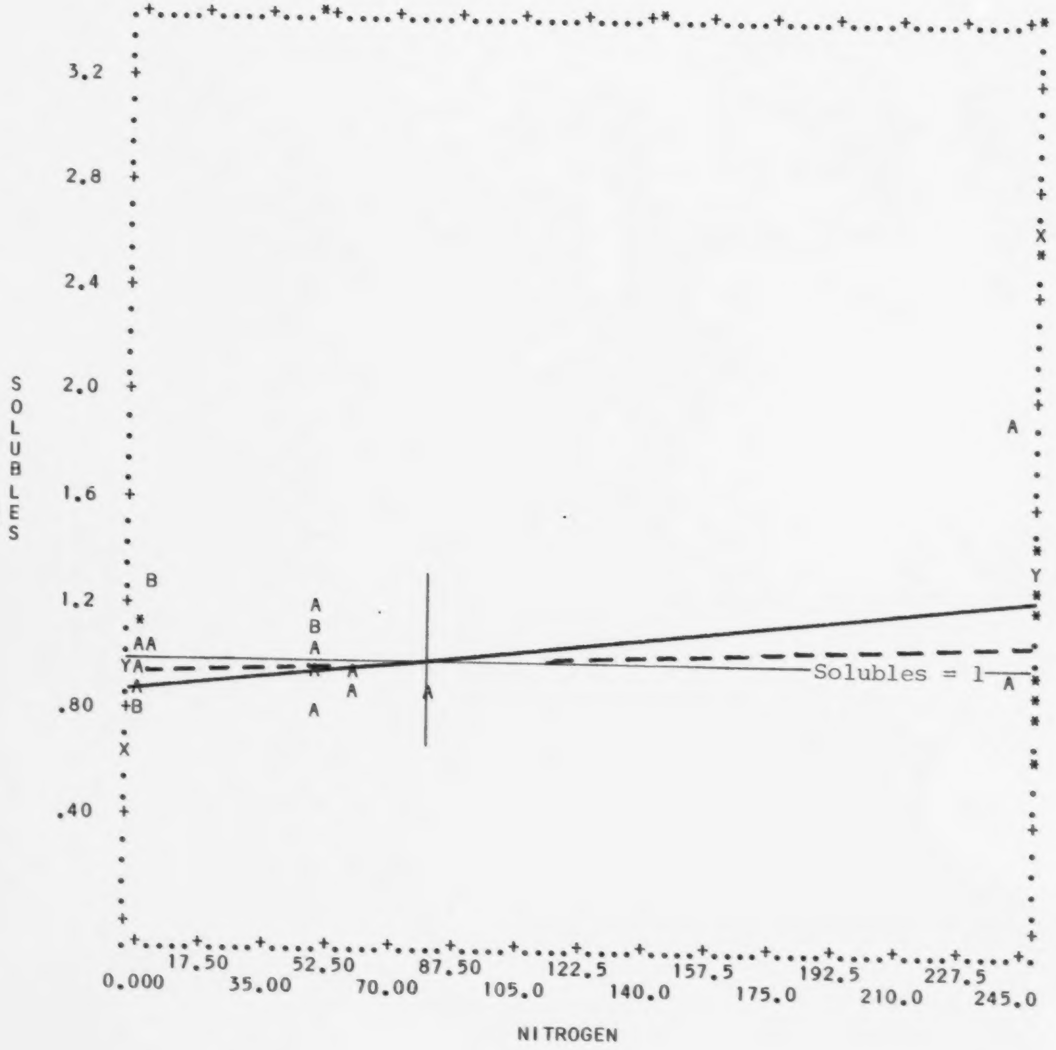
     MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X    46.810    9.8833    X=-5.0690*Y+ 51.851    93.911
Y    .99450    .42644    Y=-.00944*X+ 1.4362    .17483
```

Alternate
Dashed Line

```
N=    9
COR=-.507

     MEAN      ST.DEV.     REGRESSION LINE       RES.MS.
X    43.889    5.2784    X=-5.9836*Y+ 50.672    23.658
Y    1.1336    .44719    Y=-.04295*X+ 3.0186    .16982
```

Figure 27. Normalized solubles versus cetane.



```
                          Petroleum
N=    17                  Solid Line
COR= .492

     MEAN     ST.DEV.    REGRESSION LINE      RES.MS.
X    57.118    74.904  X= 144.73*Y-91.980     4538.4
Y    1.0302    .25442  Y= .00167*X+ .93482    .05236

                          Alternate
N=     9                  Dashed Line
COR= .815

     MEAN     ST.DEV.    REGRESSION LINE      RES.MS.
X    655.78    768.41  X= 1205.0*Y-931.56     226661
Y    1.3173    .51968  Y= 551E-6*X+ .95590    .10367
```

Figure 28. Normalized solubles versus nitrogen.

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APPENDIX A

SCOPE OF WORK
WORK ASSIGNMENT NO. 5
CONTRACT 68-03-3073

WORK ASSIGNMENT NO. 5
VEHICLE EMISSIONS FROM ALTERNATE DIESEL FUELS

Scope of Work

Objective: The area of transportation fuels is currently a very dynamic area. There are some problems with the long term outlook for conventional petroleum supplies and for this reason alternate sources of transportation fuels are actively being sought. However, most research into this area is being done in the area of processes and not in end-use emissions.

It is therefore one objective of this work to operate a light duty vehicle on three alternate source fuels and analyze its emissions for a variety of pollutants. The vehicle to be used will be the same Volkswagen previously tested on which a complete baseline exists.

The second and most important objective of this work is to analyze statistically the fuels data obtained. The data derived from the first part of this task will be combined with that derived previously from the use of different alternate source fuels in the same vehicle (the VW). The combined data will then be statistically analyzed to detect trends in emissions as a function of fuel properties. The data will be compared to data taken from vehicles operated on petroleum based fuels. This comparison will be made to see if the changes observed in the emissions from the vehicle operated with alternate source fuels are significantly different from the changes one would expect based on the knowledge derived from this previous work on petroleum fuels.

Task I - Obtain Representative Fuels

The contractor shall obtain test quantities of up to three suitable fuels in accordance with the Project Officers technical direction. It is expected that EPA shall do much of the initial work to locate suitable fuels, but the contractor should be prepared to follow-up the acquisition efforts with regards to shipping and receiving the candidate fuels. Also, the contractor should be prepared to expend effort toward contacting potential sources of alternate fuels upon the direction of the Project Officer.

APPENDIX B

TEST VEHICLE BASELINE CHECK

```
                                     CFTP  - VEHICLE EMISSIONS RESULTS -VW CHECKOUT
                                             PROJECT 05-6619-005
 TEST NO.   329X01   RUN   1
 VEHICLE MODEL   80 VW RABBIT              VEHICLE NO.1
 ENGINE 1.5 L( 90. CID) L-4                DATE    11/ 3/82                              TEST WEIGHT  1021. KG( 2250. LBS)
 TRANSMISSION M4                           BAG CART NO. 1 / CVS NO. 17                   ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
                                           DYNO NO.      2                               DIESEL     EM-329-F
 BAROMETER 746.25 MM HG(29.38 IN HG)                                                     ODOMETER  4535. KM( 2818. MILES)
 RELATIVE HUMIDITY  54. PCT                DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)
 BAG RESULTS                               ABS. HUMIDITY  9.5 GM/KG
   BAG NUMBER                                                                            NOX HUMIDITY CORRECTION FACTOR   .96
   DESCRIPTION                                  1                  2                  3                  4
                                          COLD TRANSIENT      STABILIZED        HOT TRANSIENT       STABILIZED

   BLOWER DIF P MM. H2O(IN. H2O)           914.4 (36.0)       914.4 (36.0)       914.4 (36.0)       914.4 (36.0)
   BLOWER INLET P MM. H2O(IN. H2O)         889.0 (35.0)       889.0 (35.0)       889.0 (35.0)       889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)        40.6 (105.0)       45.0 (113.0)       38.3 (101.0)       37.8 (100.0)
   BLOWER REVOLUTIONS                         4989.              8574.              4987.              8574.
   TOT FLOW STD. CU. METRES(SCF)           147.0 ( 5192.)     250.1 ( 8833.)     147.8 ( 5218.)     254.4 ( 8984.)
   THC SAMPLE METER/RANGE/PPM              31.4/11/  31.      11.4/11/  11.      26.3/11/  26.      11.7/11/  12.
   THC BCKGRD METER/RANGE/PPM               3.0/ 1/   3.       2.9/ 1/   3.       2.9/ 1/   3.       2.8/ 1/   3.
   CO  SAMPLE METER/RANGE/PPM              49.4/13/  47.      20.3/13/  18.      43.6/13/  41.      20.9/13/  19.
   CO  BCKGRD METER/RANGE/PPM                .9/13/   1.       1.2/13/   1.        .4/13/   0.        .6/13/   1.
   CO2 SAMPLE METER/RANGE/PCT              59.4/11/ .4888     63.1/12/ .2567     82.9/12/ .3611     61.4/12/ .2483
   CO2 BCKGRD METER/RANGE/PCT               7.3/11/ .0437     11.8/12/ .0400     11.9/12/ .0404     11.5/12/ .0389
   NOX SAMPLE METER/RANGE/PPM              15.1/ 2/ 15.1      10.2/ 2/ 10.2      14.4/ 2/ 14.4      10.1/ 2/ 10.1
   NOX BCKGRD METER/RANGE/PPM                .4/ 2/   .4        .4/ 2/   .4        .4/ 2/   .4        .3/ 2/   .3
   DILUTION FACTOR                            26.33              50.35              35.54              52.00
   THC CONCENTRATION PPM                      29.                 9.                23.                 9.
   CO  CONCENTRATION PPM                      45.                17.                39.                18.
   CO2 CONCENTRATION PCT                      .4467              .2174              .3219              .2101
   NOX CONCENTRATION PPM                      14.7                9.8               14.0                9.8
   FILTER WT. MG (EFFICIENCY, %)            3.700 (99.)        1.997 (96.)        2.786 (98.)        1.911 (97.)
   THC MASS GRAMS                              2.44               1.24               2.02               1.33
   CO  MASS GRAMS                              7.62               4.96               6.78               5.36
   CO2 MASS GRAMS                            1202.6              995.8              871.1              978.9
   NOX MASS GRAMS                              3.98               4.51               3.81               4.59
   PARTICULATE MASS GRAMS                      2.53               1.33               1.89               1.32

   THC  GRAMS/KM                                .42                .20                .35                .21
   CO   GRAMS/KM                               1.32                .80               1.17                .85
   CO2  GRAMS/KM                              208.6              160.0              150.1              155.8
   NOX  GRAMS/KM                                .69                .72                .66                .73
   FUEL CONSUMPTION BY CB L/100KM              8.06               6.15               5.82               6.00

   RUN TIME               SECONDS              505.               867.               504.               867.
   MEASURED DISTANCE      KM                   5.77               6.22               5.80               6.28
   SCF, DRY                                    .978       .979     .980               .979       .980     .980
        DFC, WET (DRY)                             .973( .957)                            .977( .961)
        TOT VOL (SCM) / SAM BLR (SCM)             397.2/ 78.15                           402.2/ 78.12
        KM  (MEASURED)                               11.99                                  12.09
        FUEL CONSUMPTION L/100KM                      7.07                                   5.91
 COMPOSITE RESULTS
   TEST NUMBER              329X01
   BAROMETER       MM HG    746.3                                                             3-BAG        (4-BAG)
   HUMIDITY        G/KG       9.5                     CARBON DIOXIDE          G/KM            167.3        ( 166.1)
   TEMPERATURE     DEG C     22.8                     FUEL CONSUMPTION        L/100KM           6.45       (   6.41)
                                                      HYDROCARBONS (THC)      G/KM               .29       (    .29)
                                                      CARBON MONOXIDE         G/KM              1.01       (   1.02)
                                                      OXIDES OF NITROGEN      G/KM               .70       (    .70)
                                                      PARTICULATES            G/KM              .291       (   .290)
```

```
                              C505 - VEHICLE EMISSIONS RESULTS -VW CHECKOUT
                                     PROJECT 05-6619-005
TEST NO.   329X02   RUN   2
VEHICLE MODEL    80 VW RABBIT             VEHICLE NO.1
ENGINE 1.5 L( 90. CID) L-4                DATE    11/ 4/82                TEST WEIGHT  1021. KG( 2250. LBS)
TRANSMISSION M4                           BAG CART NO.  1                 ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
                                          DYNO NO.      2                 DIESEL     EM-329-F
                                          CVS NO.  17                     ODOMETER   4561. KM( 2834. MILES)
BAROMETER 752.60 MM HG(29.63 IN HG)
RELATIVE HUMIDITY  82. PCT                DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)
BAG RESULTS                               ABS. HUMIDITY 15.0 GM/KG         NOX HUMIDITY CORRECTION FACTOR  1.16
   TEST CYCLE                                   C505

   BLOWER DIF P MM. H2O(IN. H2O)               914.4 (36.0)
   BLOWER INLET P MM. H2O(IN. H2O)             889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)            39.4 (103.0)
   BLOWER REVOLUTIONS                            4994.
   TOT FLOW STD. CU. METRES(SCF)               150.0 ( 5295.)
   THC SAMPLE METER/RANGE/PPM                  25.9/11/  26.
   THC BCKGRD METER/RANGE/PPM                   4.1/ 1/   4.
   CO  SAMPLE METER/RANGE/PPM                  46.9/13/  44.
   CO  BCKGRD METER/RANGE/PPM                   5.9/13/   5.
   CO2 SAMPLE METER/RANGE/PCT                  90.9/12/ .4082
   CO2 BCKGRD METER/RANGE/PCT                  12.8/12/ .0436
   NOX SAMPLE METER/RANGE/PPM                  15.9/ 2/ 15.9
   NOX BCKGRD METER/RANGE/PPM                    .7/ 2/   .7
   DILUTION FACTOR                                31.49
   THC CONCENTRATION PPM                          22.
   CO  CONCENTRATION PPM                          38.
   CO2 CONCENTRATION PCT                         .3660
   NOX CONCENTRATION PPM                          15.2
   FILTER WT. MG (EFFICIENCY, %)               2.906 (98.)
   THC MASS GRAMS                                  1.92
   CO  MASS GRAMS                                  6.55
   CO2 MASS GRAMS                                1004.9
   NOX MASS GRAMS                                  5.08
   PARTICULATE MASS GRAMS                          1.92
   RUN TIME              SECONDS                  505.
        DFC, WET (DRY)                         .968 ( .943)
        SCF, WET (DRY)                        1.000 ( .969)
        VOL (SCM)                                 150.0
        SAM BLR (SCM)                             29.94
        KM  (MEASURED)                             5.75

  TEST NUMBER,                                 329X02
  BAROMETER,               MM HG                752.6
  HUMIDITY,                G/KG                  15.0
  TEMPERATURE,             DEG C                 23.3
  CARBON DIOXIDE,           G/KM                174.8
  FUEL CONSUMPTION,         L/100KM              6.75

  HYDROCARBONS, (THC)       G/KM                  .33
  CARBON MONOXIDE,          G/KM                 1.14
  OXIDES OF NITROGEN,       G/KM                  .88
  PARTICULATES,             G/KM                 .334
```

APPENDIX C

GASEOUS AND PARTICULATE EMISSION RESULTS

```
                                        FTP   - VEHICLE EMISSIONS RESULTS -
                                                PROJECT 05-6619-005

TEST NO.   527F01   RUN   1                     VEHICLE NO.1                            TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                    DATE    11/ 9/82                        ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                      BAG CART NO. 1 / CVS NO. 17             DIESEL     EM-527-F
TRANSMISSION M4                                 DYNO NO.       2                        ODOMETER  4625. KM( 2874. MILES)

BAROMETER 745.74 MM HG(29.36 IN HG)             DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
RELATIVE HUMIDITY  59. PCT                      ABS. HUMIDITY 11.6 GM/KG
BAG RESULTS                                                                             NOX HUMIDITY CORRECTION FACTOR  1.03
  BAG NUMBER                                       1                   2                    3                   4
  DESCRIPTION                                COLD TRANSIENT       STABILIZED          HOT TRANSIENT        STABILIZED

  BLOWER DIF P MM. H2O(IN. H2O)              914.4 (36.0)        914.4 (36.0)         914.4 (36.0)        914.4 (36.0)
  BLOWER INLET P MM. H2O(IN. H2O)            889.0 (35.0)        889.0 (35.0)         889.0 (35.0)        889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)           34.4 ( 94.0)        35.0 ( 95.0)         36.1 ( 97.0)        37.2 ( 99.0)
  BLOWER REVOLUTIONS                           4992.               8572.                4990.               8576.
  TOT FLOW STD. CU. METRES(SCF)              149.6 ( 5282.)      256.5 ( 9058.)       148.9 ( 5258.)      255.3 ( 9013.)
  THC  SAMPLE METER/RANGE/PPM                36.1/11/  36.       14.1/11/  14.        31.9/11/  32.       13.4/11/  13.
  THC  BCKGRD METER/RANGE/PPM                 6.0/ 1/   6.        5.8/ 1/   6.         5.8/ 1/   6.        5.4/ 1/   5.
  CO   SAMPLE METER/RANGE/PPM                51.5/13/  49.       22.7/13/  21.        45.8/13/  43.       21.5/13/  20.
  CO   BCKGRD METER/RANGE/PPM                 2.5/13/   2.        2.3/13/   2.         1.8/13/   2.        2.3/13/   2.
  CO2  SAMPLE METER/RANGE/PCT                91.3/12/ .4106      62.3/12/ .2527       82.8/12/ .3606      61.1/12/ .2469
  CO2  BCKGRD METER/RANGE/PCT                12.9/12/ .0439      13.0/12/ .0443       13.0/12/ .0443      12.9/12/ .0439
  NOX  SAMPLE METER/RANGE/PPM                14.0/ 2/ 14.0        9.0/ 2/  9.0        13.1/ 2/ 13.1        9.0/ 2/  9.0
  NOX  BCKGRD METER/RANGE/PPM                 1.3/ 2/  1.3         .9/ 2/   .9          .7/ 2/   .7         .7/ 2/   .7
  DILUTION FACTOR                               31.10               50.87                35.41               52.09
  THC  CONCENTRATION PPM                         30.                  8.                  26.                  8.
  CO   CONCENTRATION PPM                         45.                 18.                  40.                 17.
  CO2  CONCENTRATION PCT                        .3681               .2093                .3175               .2038
  NOX  CONCENTRATION PPM                        12.7                 8.1                 12.4                 8.3
  FILTER WT. MG (EFFICIENCY, %)              2.611 (98.)         1.578 (99.)          1.988 (99.)         1.470 (97.)
  THC  MASS GRAMS                               2.64                1.26                 2.28                1.21
  CO   MASS GRAMS                               7.88                5.44                 6.98                5.09
  CO2  MASS GRAMS                             1008.2               983.0                865.8               952.3
  NOX  MASS GRAMS                               3.75                4.10                 3.64                4.18
  PARTICULATE MASS GRAMS                        1.81                1.06                 1.35                 .98

  THC   GRAMS/KM                                 .46                 .20                  .39                 .19
  CO    GRAMS/KM                                1.36                 .87                 1.21                 .82
  CO2   GRAMS/KM                               174.6               156.6                149.8               152.5
  NOX   GRAMS/KM                                 .65                 .65                  .63                 .67
  FUEL CONSUMPTION BY CB L/100KM                7.06                6.28                 6.06                6.12

  RUN TIME               SECONDS                505.                868.                 505.                868.
  MEASURED DISTANCE      KM                     5.77                6.28                 5.78                6.24
  SCF, DRY                                      .977                .978                 .977                .978
       DFC, WET (DRY)                                      .978                                     .978
       TOT VOL (SCM) / SAM BLR (SCM)                    .976( .957)                              .977( .959)
       KM  (MEASURED)                                  406.1/ 78.17                            404.2/ 78.14
       FUEL CONSUMPTION L/100KM                            12.05                                    12.03
                                                            6.66                                     6.09
COMPOSITE RESULTS
  TEST NUMBER                 527F01
  BAROMETER        MM HG      745.7                                                         3-BAG       (4-BAG)
  HUMIDITY         G/KG        11.6             CARBON DIOXIDE          G/KM               158.5       ( 157.2)
  TEMPERATURE      DEG C       24.4             FUEL CONSUMPTION        L/100KM             6.38       (  6.33)
                                                HYDROCARBONS (THC)      G/KM                 .31       (   .30)
                                                CARBON MONOXIDE         G/KM                1.06       (  1.05)
                                                OXIDES OF NITROGEN      G/KM                 .65       (   .65)
                                                PARTICULATES            G/KM                .216       (  .213)
                                        HFET  - VEHICLE EMISSIONS RESULTS -
                                                PROJECT 05-6619-005

TEST NO.   527H02   RUN   1                    VEHICLE NO.1                            TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                   DATE   11/ 9/82                         ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                     BAG CART NO.  1                         DIESEL    EM-527-F
TRANSMISSION M4                                DYNO NO.      2                         ODOMETER  4649. KM( 2889. MILES)
                                               CVS NO.  17

BAROMETER 745.49 MM HG(29.35 IN HG)            DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY  56. PCT                     ABS. HUMIDITY 11.3 GM/KG                NOX HUMIDITY CORRECTION FACTOR  1.02
BAG RESULTS
  TEST CYCLE                                       HFET

  BLOWER DIF P MM. H2O(IN. H2O)               927.1 (36.5)
  BLOWER INLET P MM. H2O(IN. H2O)             889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)            38.3 (101.0)
  BLOWER REVOLUTIONS                              7560.
  TOT FLOW STD. CU. METRES(SCF)               223.6 ( 7895.)
  THC SAMPLE METER/RANGE/PPM                  34.0/11/  34.
  THC BCKGRD METER/RANGE/PPM                   5.2/ 1/   5.
  CO  SAMPLE METER/RANGE/PPM                  83.0/13/  83.
  CO  BCKGRD METER/RANGE/PPM                   1.6/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                  66.7/11/ .5724
  CO2 BCKGRD METER/RANGE/PCT                   7.4/11/ .0444
  NOX SAMPLE METER/RANGE/PPM                  23.3/ 2/ 23.3
  NOX BCKGRD METER/RANGE/PPM                    .7/ 2/    .7
  DILUTION FACTOR                                 22.32
  THC CONCENTRATION PPM                            29.
  CO  CONCENTRATION PPM                            79.
  CO2 CONCENTRATION PCT                          .5300
  NOX CONCENTRATION PPM                           22.6
  FILTER WT. MG (EFFICIENCY, $)                5.691 (99.)
  THC MASS GRAMS                                  3.78
  CO  MASS GRAMS                                 20.50
  CO2 MASS GRAMS                                2169.8
  NOX MASS GRAMS                                  9.88
  PARTICULATE MASS GRAMS                          4.07
  RUN TIME            SECONDS                     765.
       DFC, WET (DRY)                          .955 ( .938)
       SCF, WET (DRY)                         1.000 ( .976)
       VOL (SCM)                                 223.6
       SAM BLR (SCM)                             42.73
       KM  (MEASURED)                            16.39

  TEST NUMBER,                                  527H02
  BARONETER,           MM HG                     745.5
  HUMIDITY,            G/KG                       11.3
  TEMPERATURE,         DEG C                      25.0
  CARBON DIOXIDE,       G/KM                     132.4
  FUEL CONSUMPTION,     L/100KM                   5.35

  HYDROCARBONS, (THC)   G/KM                       .23
  CARBON MONOXIDE,      G/KM                      1.25
  OXIDES OF NITROGEN,   G/KM                       .60
  PARTICULATES,         G/KM                      .248
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                                          IDLE  - VEHICLE EMISSIONS RESULTS -
                                                 PROJECT 05-6619-005

TEST NO.   527103   RUN   1                       VEHICLE NO.1                          TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                      DATE    11/ 9/82                      ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                        BAG CART NO.  1                       DIESEL     EM-527-F
TRANSMISSION M4                                   DYNO NO.      2                       ODOMETER  4667. KM( 2900. MILES)
                                                  CVS NO.  17

BAROMETER 745.49 MM HG(29.35 IN HG)               DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)
RELATIVE HUMIDITY  53. PCT                        ABS. HUMIDITY 11.1 GM/KG              NOX HUMIDITY CORRECTION FACTOR  1.01
BAG RESULTS
   TEST CYCLE                                        IDLE

   BLOWER DIF P MM. H2O(IN. H2O)                  927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)                889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)               37.8 (100.0)
   BLOWER REVOLUTIONS                                11864.
   TOT FLOW STD. CU. METRES(SCF)                  351.3 (12405.)
   THC SAMPLE METER/RANGE/PPM                      7.6/11/   8.
   THC BCKGRD METER/RANGE/PPM                      5.1/ 1/   5.
   CO  SAMPLE METER/RANGE/PPM                      8.4/13/   8.
   CO  BCKGRD METER/RANGE/PPM                      1.1/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                     50.8/13/ .1003
   CO2 BCKGRD METER/RANGE/PCT                     22.9/13/ .0423
   NOX SAMPLE METER/RANGE/PPM                      3.4/ 2/  3.4
   NOX BCKGRD METER/RANGE/PPM                       .7/ 2/   .7
   DILUTION FACTOR                                   127.94
   THC CONCENTRATION PPM                                3.
   CO  CONCENTRATION PPM                                6.
   CO2 CONCENTRATION PCT                              .0583
   NOX CONCENTRATION PPM                               2.7
   FILTER WT. MG (EFFICIENCY, %)                   .175 (85.)
   THC MASS GRAMS                                      .52
   CO  MASS GRAMS                                     2.65
   CO2 MASS GRAMS                                    375.1
   NOX MASS GRAMS                                     1.84
   PARTICULATE MASS GRAMS                              .14
   RUN TIME              SECONDS                    1201.
        DFC, WET (DRY)                            .992 ( .975)
        SCF, WET (DRY)                           1.000 ( .982)
        VOL (SCM)                                   351.3
        SAM BLR (SCM)                               66.81
        KM  (MEASURED)

   TEST NUMBER,                                    527103
   BAROMETER,              MM HG                    745.5
   HUMIDITY,               G/KG                      11.1
   TEMPERATURE,            DEG C                     25.6
   CARBON DIOXIDE,          G/KM
   FUEL CONSUMPTION,        L/100KM

   HYDROCARBONS, (THC)      G/KM
   CARBON MONOXIDE,         G/KM
   OXIDES OF NITROGEN,      G/KM
   PARTICULATES,            G/KM
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                                      50 KM - VEHICLE EMISSIONS RESULTS -
                                           PROJECT 05-6619-005
TEST NO.   527504   RUN   1
VEHICLE MODEL   80 VW RABBIT                VEHICLE NO.1                         TEST WEIGHT  1021. KG( 2250. LBS)
ENGINE 1.5 L( 90. CID) L-4                  DATE    11/ 9/82                     ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
TRANSMISSION M4                             BAG CART NO.  1                      DIESEL     EM-527-F
                                            DYNO NO.      2                      ODOMETER  4667. KM( 2900. MILES)
                                            CVS NO.   17

BAROMETER 744.73 MM HG(29.32 IN HG)         DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY  52. PCT                  ABS. HUMIDITY 10.6 GM/KG             NOX HUMIDITY CORRECTION FACTOR  1.00
BAG RESULTS
  TEST CYCLE                                  50 KM

  BLOWER DIF P MM. H2O(IN. H2O)             927.1 (36.5)
  BLOWER INLET P MM. H2O(IN. H2O)           889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)          36.7 ( 98.0)
  BLOWER REVOLUTIONS                            5939.
  TOT FLOW STD. CU. METRES(SCF)             175.9 ( 6210.)
  THC SAMPLE METER/RANGE/PPM                16.1/11/  16.
  THC BCKGRD METER/RANGE/PPM                 5.0/ 1/   5.
  CO  SAMPLE METER/RANGE/PPM                25.7/13/  24.
  CO  BCKGRD METER/RANGE/PPM                 1.1/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                79.8/12/ .3438
  CO2 BCKGRD METER/RANGE/PCT                12.9/12/ .0439
  NOX SAMPLE METER/RANGE/PPM                13.6/ 2/ 13.6
  NOX BCKGRD METER/RANGE/PPM                  .6/ 2/   .6
  DILUTION FACTOR                                37.48
  THC CONCENTRATION PPM                           11.
  CO  CONCENTRATION PPM                           22.
  CO2 CONCENTRATION PCT                          .3010
  NOX CONCENTRATION PPM                           13.0
  FILTER WT. MG (EFFICIENCY, %)              1.714 (97.)
  THC MASS GRAMS                                  1.16
  CO  MASS GRAMS                                  4.51
  CO2 MASS GRAMS                                 969.2
  NOX MASS GRAMS                                  4.37
  PARTICULATE MASS GRAMS                          1.16
  RUN TIME              SECONDS                  601.
       DFC, WET (DRY)                        .973 ( .957)
       SCF, WET (DRY)                       1.000 ( .980)
       VOL (SCM)                                 175.9
       SAM BLR (SCM)                             33.27
       KM  (MEASURED)                             8.33

  TEST NUMBER,                                  527504
  BAROMETER,            MM HG                    744.7
  HUMIDITY,             G/KG                      10.6
  TEMPERATURE,          DEG C                     25.0
  CARBON DIOXIDE,        G/KM                    116.3
  FUEL CONSUMPTION,      L/100KM                  4.66

  HYDROCARBONS, (THC)    G/KM                      .14
  CARBON MONOXIDE,       G/KM                      .54
  OXIDES OF NITROGEN,    G/KM                      .52
  PARTICULATES,          G/KM                      .139
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                                  85 KM - VEHICLE EMISSIONS RESULTS -
                                      PROJECT 05-6619-005

TEST NO.   527805   RUN   1               VEHICLE NO.1                       TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT              DATE   11/ 9/82                    ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                BAG CART NO.  1                    DIESEL    EM-527-F
TRANSMISSION M4                           DYNO NO.      2                    ODOMETER  4677. KM( 2906. MILES)
                                          CVS NO.  17

BARometer 741.93 MM HG(29.21 IN HG)       DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)
RELATIVE HUMIDITY  50. PCT                ABS. HUMIDITY 10.4 GM/KG           NOX HUMIDITY CORRECTION FACTOR   .99
BAG RESULTS
   TEST CYCLE                                85 KM

   BLOWER DIF P MM. H2O(IN. H2O)          927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)        889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)       41.7 (107.0)
   BLOWER REVOLUTIONS                        5933.
   TOT FLOW STD. CU. METRES(SCF)          172.9 ( 6104.)
   THC SAMPLE METER/RANGE/PPM             38.0/11/  38.
   THC BCKGRD METER/RANGE/PPM              4.9/ 1/   5.
   CO  SAMPLE METER/RANGE/PPM             99.3/13/ 101.
   CO  BCKGRD METER/RANGE/PPM               .6/13/   1.
   CO2 SAMPLE METER/RANGE/PCT             70.9/11/ .6234
   CO2 BCKGRD METER/RANGE/PCT              7.3/11/ .0437
   NOX SAMPLE METER/RANGE/PPM             26.6/ 2/ 26.6
   NOX BCKGRD METER/RANGE/PPM               .6/ 2/   .6
   DILUTION FACTOR                           20.45
   THC CONCENTRATION PPM                      33.
   CO  CONCENTRATION PPM                      98.
   CO2 CONCENTRATION PCT                     .5818
   NOX CONCENTRATION PPM                     26.0
   FILTER WT. MG (EFFICIENCY, %)          4.313 (99.)
   THC MASS GRAMS                             3.36
   CO  MASS GRAMS                            19.71
   CO2 MASS GRAMS                           1841.5
   NOX MASS GRAMS                             8.53
   PARTICULATE MASS GRAMS                     3.80
   RUN TIME               SECONDS            600.
        DFC, WET (DRY)                    .951 ( .936)
        SCF, WET (DRY)                   1.000 ( .978)
        VOL (SCM)                           172.9
        SAM BLR (SCM)                       33.00
        KM  (MEASURED)                      14.24

   TEST NUMBER,                             527805
   BAROMETER,            MM HG               741.9
   HUMIDITY,             G/KG                 10.4
   TEMPERATURE,          DEG C                25.6
   CARBON DIOXIDE,        G/KM               129.3
   FUEL CONSUMPTION,      L/100KM              5.24

   HYDROCARBONS, (THC)    G/KM                 .24
   CARBON MONOXIDE,       G/KM                1.38
   OXIDES OF NITROGEN,    G/KM                 .60
   PARTICULATES,          G/KM                 .267
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                                        FTP    - VEHICLE EMISSIONS RESULTS -
                                                 PROJECT 05-6619-005

TEST NO.   527F06    RUN   2
VEHICLE MODEL   80 VW RABBIT                VEHICLE NO.1                          TEST WEIGHT  1021. KG( 2250. LBS)
ENGINE 1.5 L( 90. CID) L-4                  DATE    11/10/82                      ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
TRANSMISSION M4                             BAG CART NO. 1 / CVS NO. 17           DIESEL    EM-527-F
                                            DYNO NO.      2                       ODOMETER  4688. KM( 2913. MILES)
BAROMETER 746.25 MM HG(29.38 IN HG)
RELATIVE HUMIDITY  60. PCT                  DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
BAG RESULTS                                 ABS. HUMIDITY 12.1 GM/KG              NOX HUMIDITY CORRECTION FACTOR  1.05
  BAG NUMBER                                       1                  2                  3                  4
  DESCRIPTION                                COLD TRANSIENT       STABILIZED        HOT TRANSIENT       STABILIZED

  BLOWER DIF P MM. H2O(IN. H2O)              914.4 (36.0)       914.4 (36.0)       914.4 (36.0)       914.4 (36.0)
  BLOWER INLET P MM. H2O(IN. H2O)            889.0 (35.0)       889.0 (35.0)       889.0 (35.0)       889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)           38.3 (101.0)       39.4 (103.0)       41.7 (107.0)       40.0 (104.0)
  BLOWER REVOLUTIONS                            4991.              8576.              4993.              8579.
  TOT FLOW STD. CU. METRES(SCF)              148.2 ( 5232.)     253.9 ( 8966.)     147.0 ( 5192.)     253.7 ( 8957.)
  THC SAMPLE METER/RANGE/PPM                21.7/12/  43.       7.4/12/  15.      15.8/12/  32.       6.2/12/  12.
  THC BCKGRD METER/RANGE/PPM                 6.0/ 1/   6.       5.8/ 1/   6.       5.8/ 1/   6.       5.4/ 1/   5.
  CO  SAMPLE METER/RANGE/PPM                55.5/13/  53.      22.7/13/  21.      45.4/13/  43.      21.0/13/  19.
  CO  BCKGRD METER/RANGE/PPM                 1.5/13/   1.       1.8/13/   2.       1.0/13/   1.       1.4/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                91.6/12/ .4125     62.3/12/ .2527     83.3/12/ .3634     61.2/12/ .2474
  CO2 BCKGRD METER/RANGE/PCT                13.2/12/ .0450     13.0/12/ .0443     13.1/12/ .0446     13.2/12/ .0450
  NOX SAMPLE METER/RANGE/PPM                12.8/ 2/ 12.8       8.4/ 2/  8.4      12.3/ 2/ 12.3       8.4/ 2/  8.4
  NOX BCKGRD METER/RANGE/PPM                  .5/ 2/   .5        .5/ 2/   .5        .5/ 2/   .5        .5/ 2/   .5
  DILUTION FACTOR                               30.88              50.85              35.15              52.03
  THC CONCENTRATION PPM                           38.                 9.                26.                 7.
  CO  CONCENTRATION PPM                           50.                19.                41.                17.
  CO2 CONCENTRATION PCT                         .3689              .2093              .3201              .2032
  NOX CONCENTRATION PPM                          12.3                7.9               11.8                7.9
  FILTER WT. MG (EFFICIENCY, %)              2.983 (99.)        1.632 (98.)        2.059 (98.)        1.469 (97.)
  THC MASS GRAMS                                 3.25               1.34               2.22               1.04
  CO  MASS GRAMS                                 8.64               5.51               6.94               5.15
  CO2 MASS GRAMS                               1000.8              973.1              861.6              943.8
  NOX MASS GRAMS                                 3.65               4.02               3.48               4.02
  PARTICULATE MASS GRAMS                         1.99               1.08               1.37                .98

  THC  GRAMS/KM                                   .56                .21                .38                .17
  CO   GRAMS/KM                                  1.50                .88               1.20                .82
  CO2  GRAMS/KM                                 173.3              154.5              149.2              150.4
  NOX  GRAMS/KM                                   .63                .64                .60                .64
  FUEL CONSUMPTION BY CB L/100KM                 7.03               6.20               6.03               6.03

  RUN TIME                SECONDS                505.               868.               505.               868.
  MEASURED DISTANCE       KM                     5.78               6.30               5.78               6.27
  SCF, DRY                                       .977      .978     .978               .977      .978     .978
       DFC, WET (DRY)                                  .976( .957)                          .977( .959)
       TOT VOL (SCM) / SAM BLR (SCM)                  402.1/ 78.05                         400.7/ 78.05
       KM  (MEASURED)                                     12.07                                12.05
       FUEL CONSUMPTION L/100KM                            6.60                                 6.03
COMPOSITE RESULTS
  TEST NUMBER              527F06
  BAROMETER      MM HG     746.3                                                            3-BAG       (4-BAG)
  HUMIDITY       G/KG       12.1                  CARBON DIOXIDE           G/KM             156.9      ( 155.7)
  TEMPERATURE    DEG C      25.0                  FUEL CONSUMPTION         L/100KM            6.32     (   6.27)
                                                  HYDROCARBONS (THC)       G/KM                .33     (    .32)
                                                  CARBON MONOXIDE          G/KM               1.09     (   1.08)
                                                  OXIDES OF NITROGEN       G/KM                .63     (    .63)
                                                  PARTICULATES             G/KM               .225     (   .220)
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                                         HFET  - VEHICLE EMISSIONS RESULTS -
                                                 PROJECT 05-6619-005
TEST NO.   527H07   RUN   2
VEHICLE MODEL   80 VW RABBIT                  VEHICLE NO.1
ENGINE 1.5 L( 90. CID) L-4                    DATE    11/10/82                   TEST WEIGHT  1021. KG( 2250. LBS)
TRANSMISSION M4                               BAG CART NO.  1                    ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
                                              DYNO NO.      2                    DIESEL    EM-527-F
                                              CVS NO.  17                        ODOMETER  4720. KM( 2933. MILES)
BAROMETER 745.49 MM HG(29.35 IN HG)
RELATIVE HUMIDITY  55. PCT                    DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
BAG RESULTS                                   ABS. HUMIDITY 10.4 GM/KG
   TEST CYCLE                                                                    NOX HUMIDITY CORRECTION FACTOR   .99
                                                 HFET
   BLOWER DIF P MM. H2O(IN. H2O)              914.4 (36.0)
   BLOWER INLET P MM. H2O(IN. H2O)            889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)           40.0 (104.0)
   BLOWER REVOLUTIONS                            7564.
   TOT FLOW STD. CU. METRES(SCF)              222.9 ( 7871.)
   THC SAMPLE METER/RANGE/PPM                 38.0/12/  76.
   THC BCKGRD METER/RANGE/PPM                  5.4/ 1/   5.
   CO  SAMPLE METER/RANGE/PPM                 94.7/13/  96.
   CO  BCKGRD METER/RANGE/PPM                  1.1/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                 67.4/11/ .5808
   CO2 BCKGRD METER/RANGE/PCT                  7.4/11/ .0444
   NOX SAMPLE METER/RANGE/PPM                 21.5/ 2/ 21.5
   NOX BCKGRD METER/RANGE/PPM                   .5/ 2/   .5
   DILUTION FACTOR                               21.80
   THC CONCENTRATION PPM                           71.
   CO  CONCENTRATION PPM                           92.
   CO2 CONCENTRATION PCT                         .5384
   NOX CONCENTRATION PPM                          21.0
   FILTER WT. MG (EFFICIENCY, $)              5.707 (99.)
   THC MASS GRAMS                                 9.20
   CO  MASS GRAMS                                23.93
   CO2 MASS GRAMS                               2197.4
   NOX MASS GRAMS                                 8.87
   PARTICULATE MASS GRAMS                         4.05
   RUN TIME              SECONDS                  766.
        DFC, WET (DRY)                        .954 ( .937)
        SCF, WET (DRY)                       1.000 ( .976)
        VOL (SCM)                                222.9
        SAM BLR (SCM)                            42.77
        KM  (MEASURED)                           16.62

TEST NUMBER,                                  527H07
BAROMETER,             MM HG                   745.5
HUMIDITY,              G/KG                     10.4
TEMPERATURE,           DEG C                    23.9
CARBON DIOXIDE,         G/KM                   132.2
FUEL CONSUMPTION,       L/100KM                 5.40

HYDROCARBONS, (THC)     G/KM                     .55
CARBON MONOXIDE,        G/KM                    1.44
OXIDES OF NITROGEN,     G/KM                     .53
PARTICULATES,           G/KM                    .243
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                         FTP   - VEHICLE EMISSIONS RESULTS -
                                 PROJECT 05-6619-005

TEST NO.   526F01   RUN   1
VEHICLE MODEL   80 VW RABBIT              VEHICLE NO.1
ENGINE 1.5 L( 90. CID) L-4                DATE    11/12/82                      TEST WEIGHT   1021. KG( 2250. LBS)
TRANSMISSION M4                           BAG CART NO. 1 / CVS NO. 17           ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
                                          DYNO NO.      2                       DIESEL     EM-526-F
                                                                                ODOMETER  4801. KM( 2983. MILES)
BAROMETER 747.78 MM HG(29.44 IN HG)
RELATIVE HUMIDITY  25. PCT                DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
BAG RESULTS                               ABS. HUMIDITY  4.6 GM/KG              NOX HUMIDITY CORRECTION FACTOR   .83
   BAG NUMBER                                    1                 2                   3                  4
   DESCRIPTION                            COLD TRANSIENT       STABILIZED         HOT TRANSIENT        STABILIZED

   BLOWER DIF P MM. H2O(IN. H2O)          939.8 (37.0)       927.1 (36.5)        927.1 (36.5)       927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)        914.4 (36.0)       889.0 (35.0)        889.0 (35.0)       889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)       35.0 ( 95.0)       36.1 ( 97.0)        36.1 ( 97.0)       36.7 ( 98.0)
   BLOWER REVOLUTIONS                       4982.              8566.               4988.              8570.
   TOT FLOW STD. CU. METRES(SCF)          148.9 ( 5258.)     256.2 ( 9045.)      149.2 ( 5267.)     255.9 ( 9037.)
   THC SAMPLE METER/RANGE/PPM             16.7/12/  33.       9.7/12/  19.       13.7/12/  27.       7.5/12/  15.
   THC BCKGRD METER/RANGE/PPM              3.0/ 1/   3.       3.0/ 1/   3.        3.0/ 1/   3.       2.8/ 2/   6.
   CO  SAMPLE METER/RANGE/PPM             48.8/13/  46.      23.8/13/  22.       46.6/13/  44.      26.0/13/  24.
   CO  BCKGRD METER/RANGE/PPM              1.2/13/   1.       1.2/13/   1.        1.4/13/   1.       1.4/13/   1.
   CO2 SAMPLE METER/RANGE/PCT             94.7/12/ .4318     63.8/12/ .2601      84.9/12/ .3726     62.9/12/ .2557
   CO2 BCKGRD METER/RANGE/PCT             12.3/12/ .0418     12.3/12/ .0418      11.9/12/ .0404     12.3/12/ .0418
   NOX SAMPLE METER/RANGE/PPM             18.5/ 2/ 18.5      12.0/ 2/ 12.0       17.7/ 2/ 17.7      11.8/ 2/ 11.8
   NOX BCKGRD METER/RANGE/PPM               .6/ 2/   .6        .7/ 2/   .7         .5/ 2/   .5        .6/ 2/   .6
   DILUTION FACTOR                          30.67              51.04               35.52              51.96
   THC CONCENTRATION PPM                     31.                16.                 24.                10.
   CO  CONCENTRATION PPM                     44.                20.                 42.                22.
   CO2 CONCENTRATION PCT                    .3914              .2191               .3334              .2147
   NOX CONCENTRATION PPM                     17.9               11.3                17.2               11.2
   FILTER WT. MG (EFFICIENCY, %)          4.005 (99.)        2.278 (97.)         2.693 (99.)        1.687 (96.)
   THC MASS GRAMS                            2.62               2.43                2.10               1.40
   CO  MASS GRAMS                            7.66               6.08                7.27               6.63
   CO2 MASS GRAMS                          1067.0             1027.8               910.4             1005.9
   NOX MASS GRAMS                            4.25               4.62                4.09               4.57
   PARTICULATE MASS GRAMS                    2.78               1.59                1.87               1.17

   THC   GRAMS/KM                             .45                .38                 .36                .22
   CO    GRAMS/KM                            1.32                .96                1.25               1.04
   CO2   GRAMS/KM                           183.4              161.7               157.0              157.1
   NOX   GRAMS/KM                             .73                .73                 .71                .71
   FUEL CONSUMPTION BY CB L/100KM            6.83               6.00                5.85               5.82

   RUN TIME               SECONDS            504.               867.                505.               867.
   MEASURED DISTANCE      KM                 5.82               6.36                5.80               6.40
   SCF, DRY                                  .988               .990                .989               .990
        DFC, WET (DRY)                                 .989                                    .989
        TOT VOL (SCM) / SAM BLR (SCM)              .976( .968)                             .977( .970)
        KM  (MEASURED)                            405.1/ 78.27                            405.1/ 78.30
        FUEL CONSUMPTION L/100KM                      12.17                                   12.20
                                                       6.40                                    5.83
COMPOSITE RESULTS
   TEST NUMBER             526F01                                                                3-BAG      (4-BAG)
   BAROMETER     MM HG     747.8                      CARBON DIOXIDE          G/KM         164.9      ( 163.5)
   HUMIDITY      G/KG        4.6                      FUEL CONSUMPTION        L/100KM        6.13      (   6.08)
   TEMPERATURE   DEG C      23.9                      HYDROCARBONS (THC)      G/KM            .39      (    .34)
                                                      CARBON MONOXIDE         G/KM           1.11      (   1.13)
                                                      OXIDES OF NITROGEN      G/KM            .72      (    .72)
                                                      PARTICULATES            G/KM           .316      (   .296)
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                                     HFET  - VEHICLE EMISSIONS RESULTS -
                                              PROJECT 05-6619-005
TEST NO.   526H02   RUN   1
VEHICLE MODEL   80 VW RABBIT               VEHICLE NO.1
ENGINE 1.5 L( 90. CID) L-4                 DATE    11/12/82                  TEST WEIGHT  1021. KG( 2250. LBS)
TRANSMISSION M4                            BAG CART NO.  1                   ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
                                           DYNO NO.      2                   DIESEL    EM-526-F
BAROMETER 747.78 MM HG(29.44 IN HG)        CVS NO.  17                       ODOMETER  4826. KM( 2999. MILES)
RELATIVE HUMIDITY  24. PCT
BAG RESULTS                                DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
   TEST CYCLE                              ABS. HUMIDITY  4.8 GM/KG
                                                                             NOX HUMIDITY CORRECTION FACTOR   .84
   BLOWER DIF P MM. H2O(IN. H2O)              HFET
   BLOWER INLET P MM. H2O(IN. H2O)          965.2 (38.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)        939.8 (37.0)
   BLOWER REVOLUTIONS                        36.7 ( 98.0)
   TOT FLOW STD. CU. METRES(SCF)              7565.
   THC SAMPLE METER/RANGE/PPM               223.8 ( 7902.)
   THC BCKGRD METER/RANGE/PPM               26.0/12/  52.
   CO  SAMPLE METER/RANGE/PPM                3.0/ 1/   3.
   CO  BCKGRD METER/RANGE/PPM               81.3/13/  81.
   CO2 SAMPLE METER/RANGE/PCT                 .2/13/   0.
   CO2 BCKGRD METER/RANGE/PCT               70.2/11/ .6148
   NOX SAMPLE METER/RANGE/PPM                6.8/11/ .0406
   NOX BCKGRD METER/RANGE/PPM               36.2/ 2/ 36.2
   DILUTION FACTOR                           1.9/ 2/  1.9
   THC CONCENTRATION PPM                        21.48
   CO  CONCENTRATION PPM                          49.
   CO2 CONCENTRATION PCT                          79.
   NOX CONCENTRATION PPM                        .5761
   FILTER WT. MG (EFFICIENCY, %)                 34.4
   THC MASS GRAMS                            7.071 (99.)
   CO  MASS GRAMS                                6.33
   CO2 MASS GRAMS                               20.55
   NOX MASS GRAMS                              2360.2
   PARTICULATE MASS GRAMS                       12.30
   RUN TIME             SECONDS                  5.19
        DFC, WET (DRY)                           766.
        SCF, WET (DRY)                       .953 ( .946)
        VOL (SCM)                           1.000 ( .987)
        SAM BLR (SCM)                           223.8
        KM  (MEASURED)                          42.94
TEST NUMBER,                                    16.55
BAROMETER,              MM HG                  526H02
HUMIDITY,               G/KG                    747.8
TEMPERATURE,            DEG C                     4.8
CARBON DIOXIDE,          G/KM                    25.0
FUEL CONSUMPTION,        L/100KM                142.6
                                                 5.32
HYDROCARBONS, (THC)     G/KM
CARBON MONOXIDE,        G/KM                      .38
OXIDES OF NITROGEN,     G/KM                     1.24
PARTICULATES,           G/KM                      .74
                                                 .314
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                                   IDLE  - VEHICLE EMISSIONS RESULTS -
                                             PROJECT 05-6619-005

TEST NO.   526103   RUN   1                 VEHICLE NO.1                   TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                DATE   11/12/82                ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                  BAG CART NO.  1                DIESEL    EM-526-F
TRANSMISSION M4                             DYNO NO.      2                ODOMETER  4844. KM( 3010. MILES)
                                            CVS NO.  17

BAROMETER 748.03 MM HG(29.45 IN HG)         DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
RELATIVE HUMIDITY  26. PCT                  ABS. HUMIDITY  5.0 GM/KG       NOX HUMIDITY CORRECTION FACTOR   .84
BAG RESULTS
   TEST CYCLE                                  IDLE

   BLOWER DIF P MM. H2O(IN. H2O)            927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)          889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)         36.1 ( 97.0)
   BLOWER REVOLUTIONS                          11864.
   TOT FLOW STD. CU. METRES(SCF)            354.1 (12502.)
   THC SAMPLE METER/RANGE/PPM               20.7/11/  21.
   THC BCKGRD METER/RANGE/PPM                3.2/ 1/   3.
   CO  SAMPLE METER/RANGE/PPM               22.6/13/  21.
   CO  BCKGRD METER/RANGE/PPM                 .5/13/   0.
   CO2 SAMPLE METER/RANGE/PCT               47.1/13/ .0924
   CO2 BCKGRD METER/RANGE/PCT               20.6/13/ .0378
   NOX SAMPLE METER/RANGE/PPM                4.8/ 2/  4.8
   NOX BCKGRD METER/RANGE/PPM                1.7/ 2/  1.7
   DILUTION FACTOR                              139.69
   THC CONCENTRATION PPM                         18.
   CO  CONCENTRATION PPM                         20.
   CO2 CONCENTRATION PCT                        .0549
   NOX CONCENTRATION PPM                         3.1
   FILTER WT. MG (EFFICIENCY, %)              .445 (83.)
   THC MASS GRAMS                                3.58
   CO  MASS GRAMS                                8.23
   CO2 MASS GRAMS                               355.9
   NOX MASS GRAMS                                1.77
   PARTICULATE MASS GRAMS                         .37
   RUN TIME            SECONDS                  1200.
        DFC, WET (DRY)                       .993 ( .985)
        SCF, WET (DRY)                      1.000 ( .991)
        VOL (SCM)                               354.1
        SAM BLR (SCM)                           67.29
        KM  (MEASURED)                           5.00

   TEST NUMBER,                                526103
   BAROMETER,            MM HG                  748.0
   HUMIDITY,             G/KG                     5.0
   TEMPERATURE,          DEG C                   24.4
   CARBON DIOXIDE,        G/KM                   71.2
   FUEL CONSUMPTION,      L/100KM                2.78

   HYDROCARBONS, (THC)    G/KM                    .72
   CARBON MONOXIDE,       G/KM                   1.65
   OXIDES OF NITROGEN,    G/KM                    .35
   PARTICULATES,          G/KM                   .074
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                                     50 KPH- VEHICLE EMISSIONS RESULTS -
                                          PROJECT 05-6619-005

TEST NO.   526504   RUN   1                VEHICLE NO.1                       TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT               DATE    11/12/82                   ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                 BAG CART NO.  1                    DIESEL    EM-526-F
TRANSMISSION M4                            DYNO NO.      2                    ODOMETER  4844. KM( 3010. MILES)
                                           CVS NO.  17

BAROMETER 748.28 MM HG(29.46 IN HG)        DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY  27. PCT                 ABS. HUMIDITY  5.3 GM/KG           NOX HUMIDITY CORRECTION FACTOR   .85
BAG RESULTS
  TEST CYCLE                                 50 KPH

  BLOWER DIF P MM. H2O(IN. H2O)            927.1 (36.5)
  BLOWER INLET P MM. H2O(IN. H2O)          889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)         36.7 ( 98.0)
  BLOWER REVOLUTIONS                          5934.
  TOT FLOW STD. CU. METRES(SCF)            176.8 ( 6242.)
  THC SAMPLE METER/RANGE/PPM               16.9/12/  34.
  THC BCKGRD METER/RANGE/PPM                3.0/ 1/   3.
  CO  SAMPLE METER/RANGE/PPM               35.1/13/  32.
  CO  BCKGRD METER/RANGE/PPM                 .1/13/   0.
  CO2 SAMPLE METER/RANGE/PCT               80.1/12/ .3454
  CO2 BCKGRD METER/RANGE/PCT               11.8/12/ .0400
  NOX SAMPLE METER/RANGE/PPM               16.9/ 2/ 16.9
  NOX BCKGRD METER/RANGE/PPM                1.4/ 2/  1.4
  DILUTION FACTOR                             38.31
  THC CONCENTRATION PPM                        31.
  CO  CONCENTRATION PPM                        32.
  CO2 CONCENTRATION PCT                       .3065
  NOX CONCENTRATION PPM                        15.5
  FILTER WT. MG (EFFICIENCY, %)             2.178 (96.)
  THC MASS GRAMS                               3.14
  CO  MASS GRAMS                               6.56
  CO2 MASS GRAMS                              991.8
  NOX MASS GRAMS                               4.46
  PARTICULATE MASS GRAMS                       1.50
  RUN TIME             SECONDS                600.
       DFC, WET (DRY)                       .974 ( .965)
       SCF, WET (DRY)                      1.000 ( .988)
       VOL (SCM)                              176.8
       SAM BLR (SCM)                          33.92
       KM  (MEASURED)                          8.35

  TEST NUMBER,                               526504
  BAROMETER,           MM HG                  748.3
  HUMIDITY,            G/KG                     5.3
  TEMPERATURE,         DEG C                   25.0
  CARBON DIOXIDE,       G/KM                  118.7
  FUEL CONSUMPTION,     L/100KM                4.42

  HYDROCARBONS, (THC)   G/KM                    .38
  CARBON MONOXIDE,      G/KM                    .79
  OXIDES OF NITROGEN,   G/KM                    .53
  PARTICULATES,         G/KM                   .179
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                                              85 KPH- VEHICLE EMISSIONS RESULTS -
                                                   PROJECT 05-6619-005

TEST NO.   526805   RUN   1
VEHICLE MODEL   80 VW RABBIT                    VEHICLE NO.1
ENGINE 1.5 L( 90. CID) L-4                      DATE    11/12/82                    TEST WEIGHT  1021. KG( 2250. LBS)
TRANSMISSION M4                                 BAG CART NO.  1                     ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
                                                DYNO NO.      2                     DIESEL     EM-526-F
                                                CVS NO.   17                        ODOMETER  4854. KM( 3016. MILES)

BAROMETER 748.54 MM HG(29.47 IN HG)
RELATIVE HUMIDITY  24. PCT                      DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
BAG RESULTS                                     ABS. HUMIDITY  4.7 GM/KG
  TEST CYCLE                                                                        NOX HUMIDITY CORRECTION FACTOR    .84
                                                  85 KPH

  BLOWER DIF P MM. H2O(IN. H2O)                  927.1 (36.5)
  BLOWER INLET P MM. H2O(IN. H2O)                889.0 (35.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)               39.4 (103.0)
  BLOWER REVOLUTIONS                               5933.
  TOT FLOW STD. CU. METRES(SCF)                  175.5 ( 6197.)
  THC SAMPLE METER/RANGE/PPM                     26.2/12/  52.
  THC BCKGRD METER/RANGE/PPM                      3.0/ 1/   3.
  CO  SAMPLE METER/RANGE/PPM                     81.1/13/  80.
  CO  BCKGRD METER/RANGE/PPM                       .5/13/   0.
  CO2 SAMPLE METER/RANGE/PCT                     74.8/11/ .6729
  CO2 BCKGRD METER/RANGE/PCT                      6.9/11/ .0412
  NOX SAMPLE METER/RANGE/PPM                     38.4/ 2/ 38.4
  NOX BCKGRD METER/RANGE/PPM                      1.4/ 2/  1.4
  DILUTION FACTOR                                     19.66
  THC CONCENTRATION PPM                               50.
  CO  CONCENTRATION PPM                               78.
  CO2 CONCENTRATION PCT                              .6338
  NOX CONCENTRATION PPM                               37.1
  FILTER WT. MG (EFFICIENCY, %)                   5.845 (99.)
  THC MASS GRAMS                                      5.00
  CO  MASS GRAMS                                     16.00
  CO2 MASS GRAMS                                    2036.3
  NOX MASS GRAMS                                     10.40
  PARTICULATE MASS GRAMS                              4.41
  RUN TIME              SECONDS                      600.
       DFC, WET (DRY)                             .949 ( .942)
       SCF, WET (DRY)                            1.000 ( .986)
       VOL (SCM)                                     175.5
       SAM BLR (SCM)                                 33.81
       KM  (MEASURED)                                14.24

  TEST NUMBER,                                      526805
  BAROMETER,            MM HG                        748.5
  HUMIDITY,             G/KG                          4.7
  TEMPERATURE,          DEG C                        25.0
  CARBON DIOXIDE,        G/KM                        143.0
  FUEL CONSUMPTION,     L/100KM                       5.33

  HYDROCARBONS, (THC)   G/KM                           .35
  CARBON MONOXIDE,      G/KM                          1.12
  OXIDES OF NITROGEN,   G/KM                           .73
  PARTICULATES,         G/KM                          .309
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                                   FTP   - VEHICLE EMISSIONS RESULTS -
                                            PROJECT 05-6619-005

TEST NO.    526F06   RUN   2                      VEHICLE NO.1                          TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                      DATE    11/15/82                      ACTUAL ROAD LOAD   5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                        BAG CART NO. 1 / CVS NO. 17           DIESEL    EM-526-F
TRANSMISSION M4                                   DYNO NO.      2                       ODOMETER  4881. KM( 3033. MILES)

BAROMETER 753.87 MM HG(29.68 IN HG)               DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY  16. PCT                        ABS. HUMIDITY  2.9 GM/KG              NOX HUMIDITY CORRECTION FACTOR   .80
BAG RESULTS
   BAG NUMBER                                         1                  2                  3                  4
   DESCRIPTION                                  COLD TRANSIENT       STABILIZED       HOT TRANSIENT       STABILIZED

   BLOWER DIF P MM. H2O(IN. H2O)                 927.1 (36.5)      939.8 (37.0)      927.1 (36.5)      927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)               914.4 (36.0)      927.1 (36.5)      914.4 (36.0)      914.4 (36.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)             42.8 (109.0)      36.7 ( 98.0)      36.1 ( 97.0)      36.1 ( 97.0)
   BLOWER REVOLUTIONS                               4989.             8576.             4991.             8576.
   TOT FLOW STD. CU. METRES(SCF)                148.3 ( 5237.)    258.2 ( 9118.)    150.7 ( 5322.)    259.0 ( 9146.)
   THC SAMPLE METER/RANGE/PPM                   20.1/12/  40.      7.9/12/  16.     14.0/12/  28.      7.3/12/  15.
   THC BCKGRD METER/RANGE/PPM                    4.0/ 1/   4.      6.0/ 1/   6.      6.0/ 1/   6.      6.0/ 1/   6.
   CO  SAMPLE METER/RANGE/PPM                   48.8/13/  46.     23.8/13/  22.     46.6/13/  44.     26.0/13/  24.
   CO  BCKGRD METER/RANGE/PPM                    1.2/13/   1.      1.2/13/   1.      1.4/13/   1.      1.4/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                   94.7/12/ .4318    63.8/12/ .2601    84.9/12/ .3726    62.9/12/ .2557
   CO2 BCKGRD METER/RANGE/PCT                   12.3/12/ .0418    12.3/12/ .0418    11.9/12/ .0404    12.3/12/ .0418
   NOX SAMPLE METER/RANGE/PPM                   18.5/ 2/ 18.5     12.0/ 2/ 12.0     17.7/ 2/ 17.7     11.8/ 2/ 11.8
   NOX BCKGRD METER/RANGE/PPM                    .6/ 2/   .6       .7/ 2/   .7       .5/ 2/   .5       .6/ 2/   .6
   DILUTION FACTOR                                  30.62             51.11             35.51             51.97
   THC CONCENTRATION PPM                            36.               10.               22.                9.
   CO  CONCENTRATION PPM                            44.               20.               42.               22.
   CO2 CONCENTRATION PCT                            .3914             .2191             .3334             .2147
   NOX CONCENTRATION PPM                            17.9              11.3              17.2              11.2
   FILTER WT. MG (EFFICIENCY, %)                 3.597 (99.)       1.741 (97.)       1.906 (97.)       2.867 (98.)
   THC MASS GRAMS                                   3.10              1.48              1.92              1.31
   CO  MASS GRAMS                                   7.65              6.15              7.37              6.73
   CO2 MASS GRAMS                                   1062.6            1036.0            920.0             1018.1
   NOX MASS GRAMS                                   4.04              4.45              3.95              4.42
   PARTICULATE MASS GRAMS                           2.39              1.21              1.30              1.99

   THC   GRAMS/KM                                    .54               .24               .33               .21
   CO    GRAMS/KM                                   1.33               .98              1.27              1.07
   CO2   GRAMS/KM                                   184.7             165.8             159.1             161.8
   NOX   GRAMS/KM                                    .70               .71               .68               .70
   FUEL CONSUMPTION BY CB L/100KM                   6.88              6.14              5.92              5.99

   RUN TIME              SECONDS                    505.              867.              505.              868.
   MEASURED DISTANCE     KM                         5.75              6.25              5.78              6.29
   SCF, DRY                                         .991      .992    .993              .992      .992    .993
        DFC, WET (DRY)                                    .976( .971)                         .977( .973)
        TOT VOL (SCM) / SAM BLR (SCM)                    406.5/ 80.25                        409.7/ 80.19
        KM  (MEASURED)                                      12.00                               12.08
        FUEL CONSUMPTION L/100KM                            6.50                                5.96

COMPOSITE RESULTS                                                                             3-BAG      (4-BAG)
   TEST NUMBER              526F06                                 CARBON DIOXIDE      G/KM     167.8     ( 166.7)
   BAROMETER      MM HG     753.9                                  FUEL CONSUMPTION    L/100KM    6.23     (  6.19)
   HUMIDITY       G/KG        2.9                                  HYDROCARBONS (THC)  G/KM       .32     (   .32)
   TEMPERATURE    DEG C      23.9                                  CARBON MONOXIDE     G/KM      1.13     (  1.16)
                                                                   OXIDES OF NITROGEN  G/KM       .70     (   .70)
                                                                   PARTICULATES        G/KM      .248     (  .284)
                                   HFET  - VEHICLE EMISSIONS RESULTS -
                                              PROJECT 05-6619-005

TEST NO.   526H07   RUN   2                        VEHICLE NO.1                         TEST WEIGHT  1021. KG( 2250. LBS)
VEHICLE MODEL   80 VW RABBIT                       DATE    11/15/82                     ACTUAL ROAD LOAD    5.4 KW(  7.3 HP)
ENGINE 1.5 L( 90. CID) L-4                         BAG CART NO.  1                      DIESEL     EM-526-F
TRANSMISSION M4                                    DYNO NO.      2                      ODOMETER  4907. KM( 3049. MILES)
                                                   CVS NO.   17

BAROMETER 752.60 MM HG(29.63 IN HG)                DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY  19. PCT                         ABS. HUMIDITY  3.5 GM/KG             NOX HUMIDITY CORRECTION FACTOR   .81
BAG RESULTS
   TEST CYCLE                                         HFET

   BLOWER DIF P MM. H2O(IN. H2O)                  927.1 (36.5)
   BLOWER INLET P MM. H2O(IN. H2O)                889.0 (35.0)
   BLOWER INLET TEMP. DEG. C(DEG. F)               37.2 ( 99.0)
   BLOWER REVOLUTIONS                                7565.
   TOT FLOW STD. CU. METRES(SCF)                  227.0 ( 8014.)
   THC SAMPLE METER/RANGE/PPM                     28.2/12/  56.
   THC BCKGRD METER/RANGE/PPM                      7.0/ 1/   7.
   CO  SAMPLE METER/RANGE/PPM                     85.0/13/  85.
   CO  BCKGRD METER/RANGE/PPM                      1.8/13/   2.
   CO2 SAMPLE METER/RANGE/PCT                     69.8/11/ .6099
   CO2 BCKGRD METER/RANGE/PCT                      7.0/11/ .0419
   NOX SAMPLE METER/RANGE/PPM                     34.7/ 2/ 34.7
   NOX BCKGRD METER/RANGE/PPM                       .5/ 2/   .5
   DILUTION FACTOR                                    21.62
   THC CONCENTRATION PPM                               50.
   CO  CONCENTRATION PPM                               82.
   CO2 CONCENTRATION PCT                              .5699
   NOX CONCENTRATION PPM                              34.2
   FILTER WT. MG (EFFICIENCY, $)                   7.761 (99.)
   THC MASS GRAMS                                      6.48
   CO  MASS GRAMS                                     21.61
   CO2 MASS GRAMS                                    2368.3
   NOX MASS GRAMS                                     11.99
   PARTICULATE MASS GRAMS                              5.65
   RUN TIME                SECONDS                     765.
        DFC, WET (DRY)                            .954 ( .948)
        SCF, WET (DRY)                           1.000 ( .988)
        VOL (SCM)                                     227.0
        SAM BLR (SCM)                                 43.48
        KM  (MEASURED)                                16.54

   TEST NUMBER,                                     526H07
   BARQMETER,              MM HG                     752.6
   HUMIDITY,               G/KG                        3.5
   TEMPERATURE,            DEG C                      23.9
   CARBON DIOXIDE,         G/KM                      143.2
   FUEL CONSUMPTION,       L/100KM                    5.35

   HYDROCARBONS, (THC)     G/KM                        .39
   CARBON MONOXIDE,        G/KM                       1.31
   OXIDES OF NITROGEN,     G/KM                        .73
   PARTICULATES,           G/KM                        .342
```

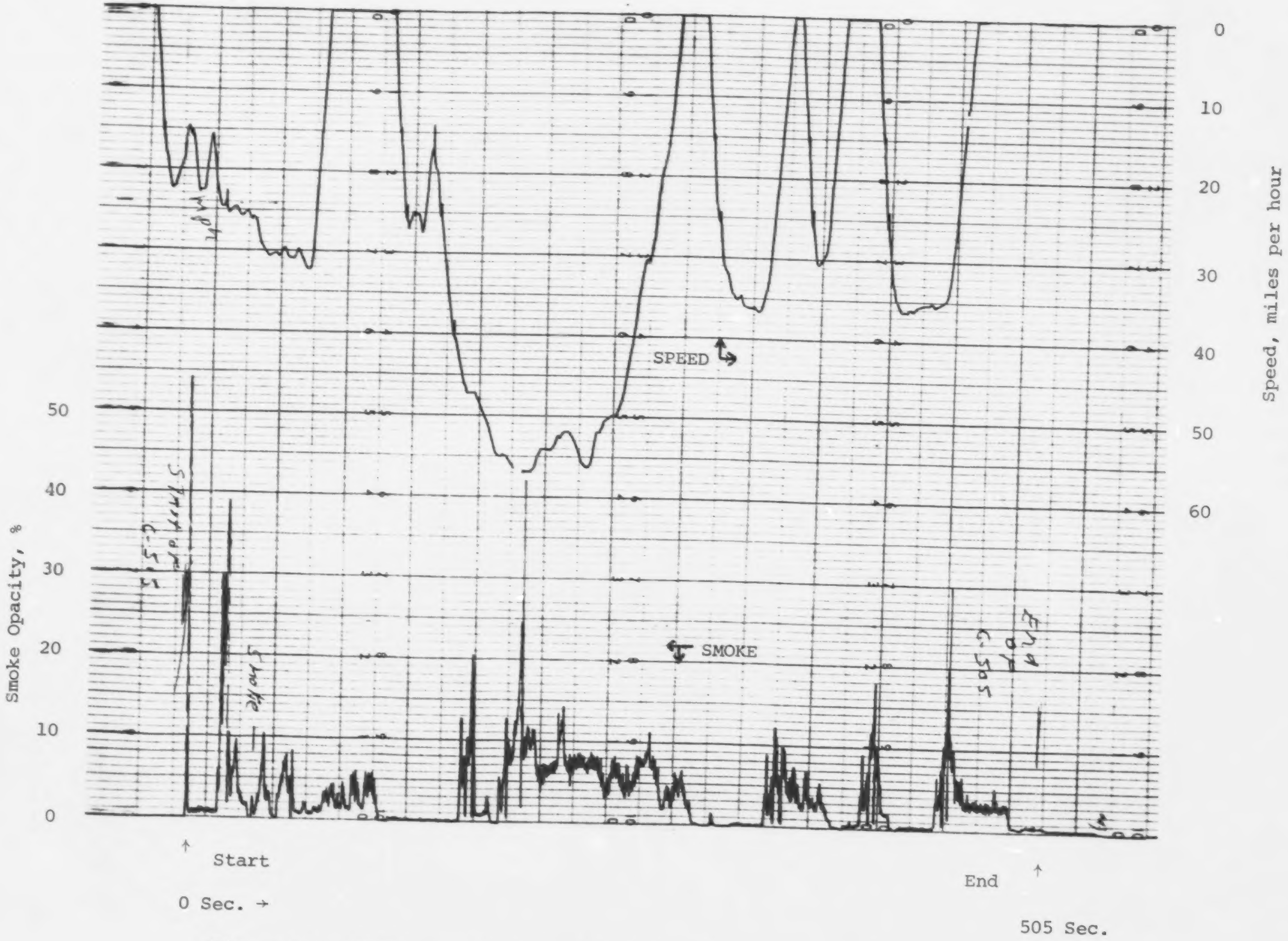

Figure C-1. Smoke opacity and vehicle speed vs. time for the first 505 seconds of a cold-start FTP, VW Rabbit Diesel, EM-527-F, SASOL, 11/11/82.

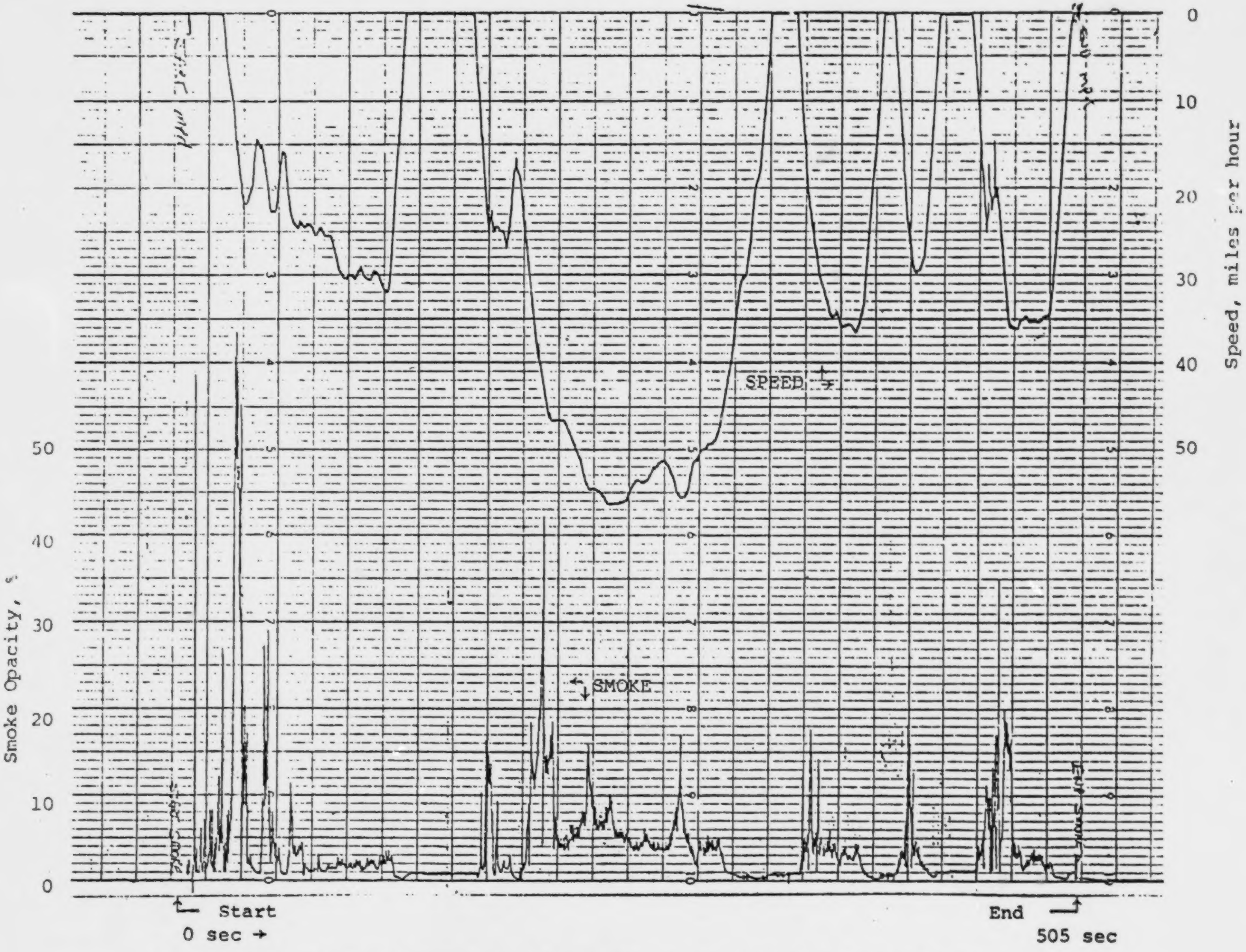

Figure C-2. Smoke opacity and vehicle speed vs time for the first 505 seconds of a cold-start FTP, VW Rabbit Diesel, EM-478-F, 25% SRC-II, 7/21/81 The trace is similar to what was observed using EM-526, 25% H-Coal.

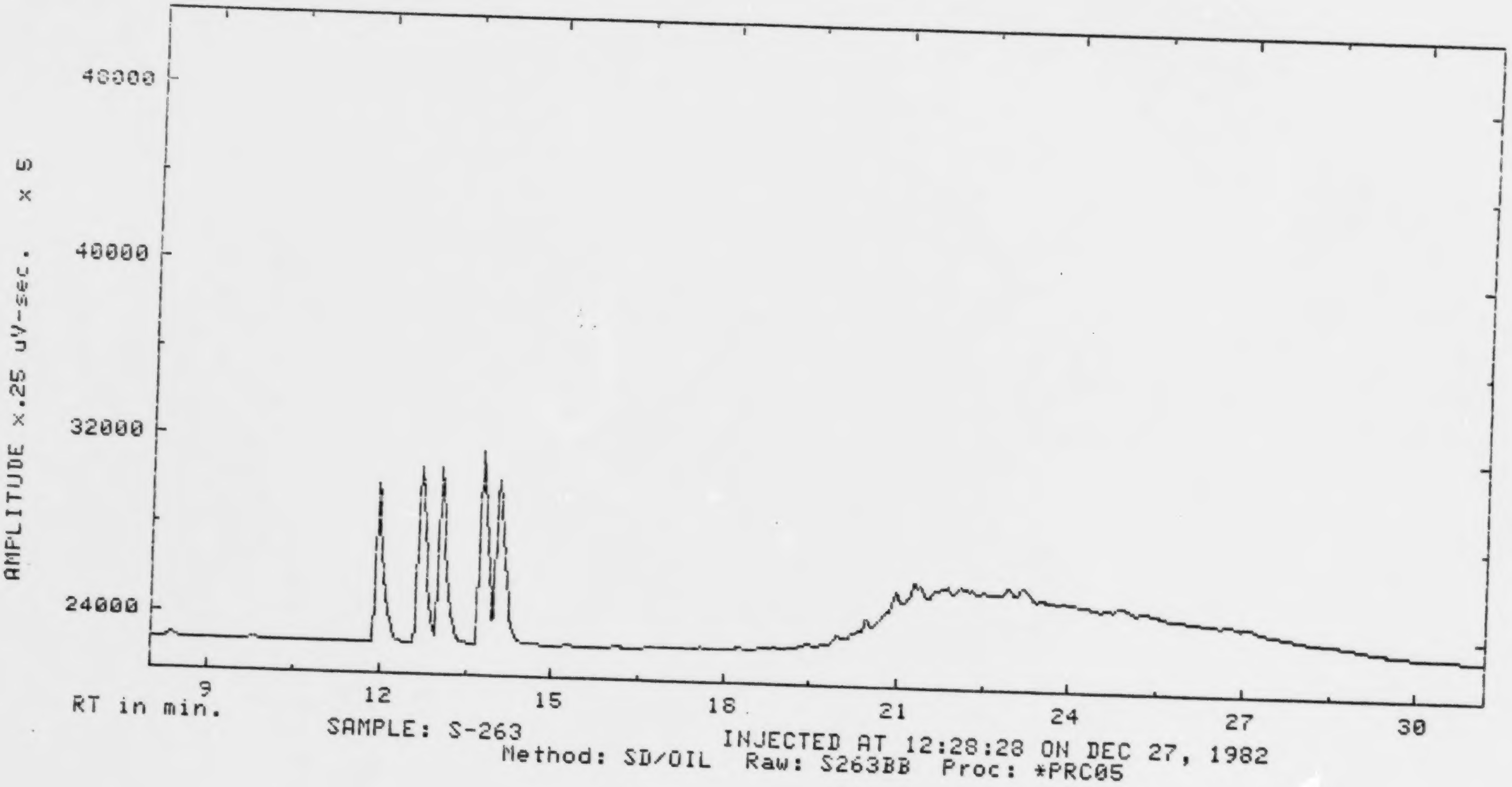

Figure C-3. Chromatogram of organic solubles from particulate matter, vehicle operated on EM-527-F fuel during FTP.

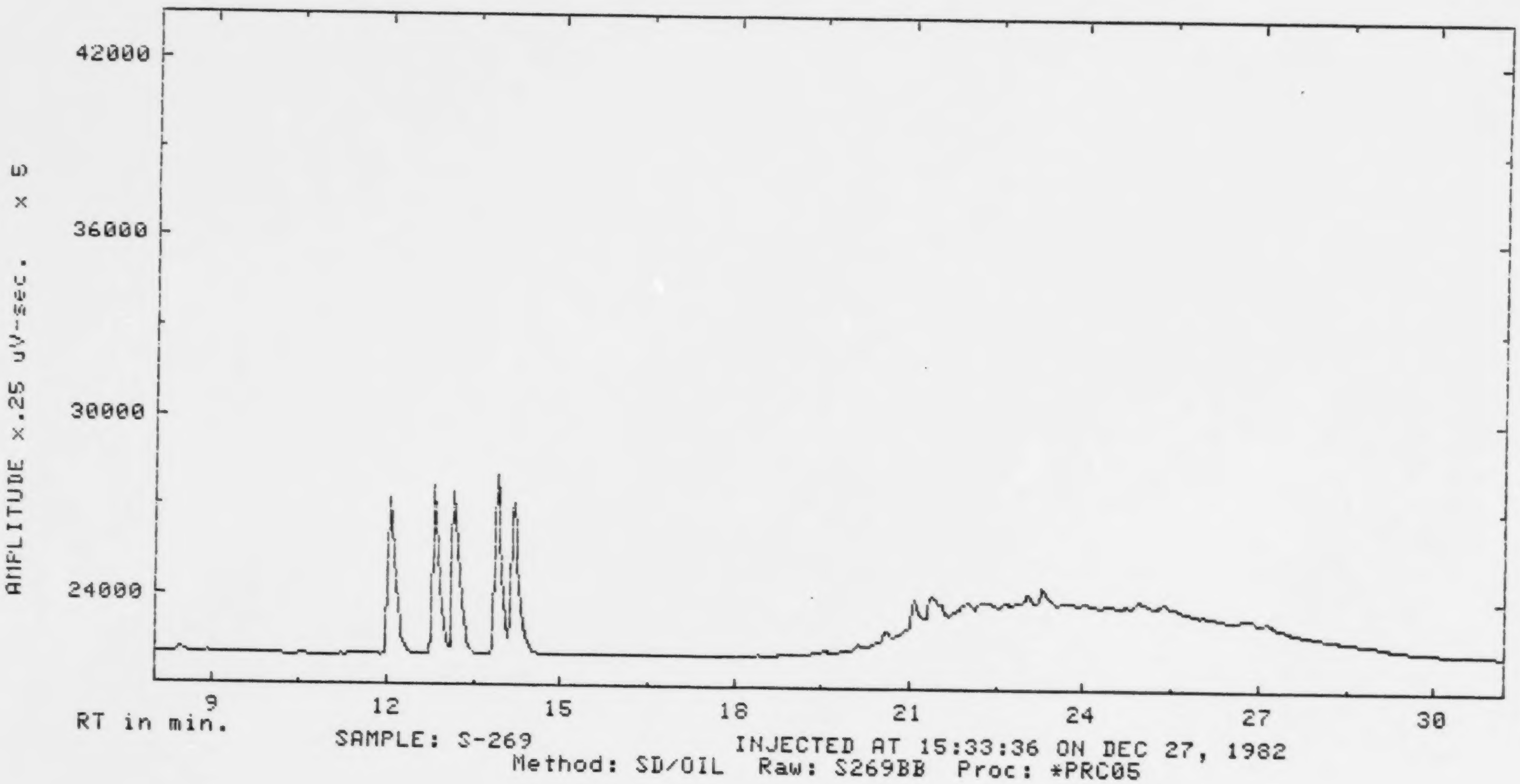

Figure C-4. Chromatogram of organic solubles from particulate matter, vehicle operated on EM-527-F fuel during HFET.

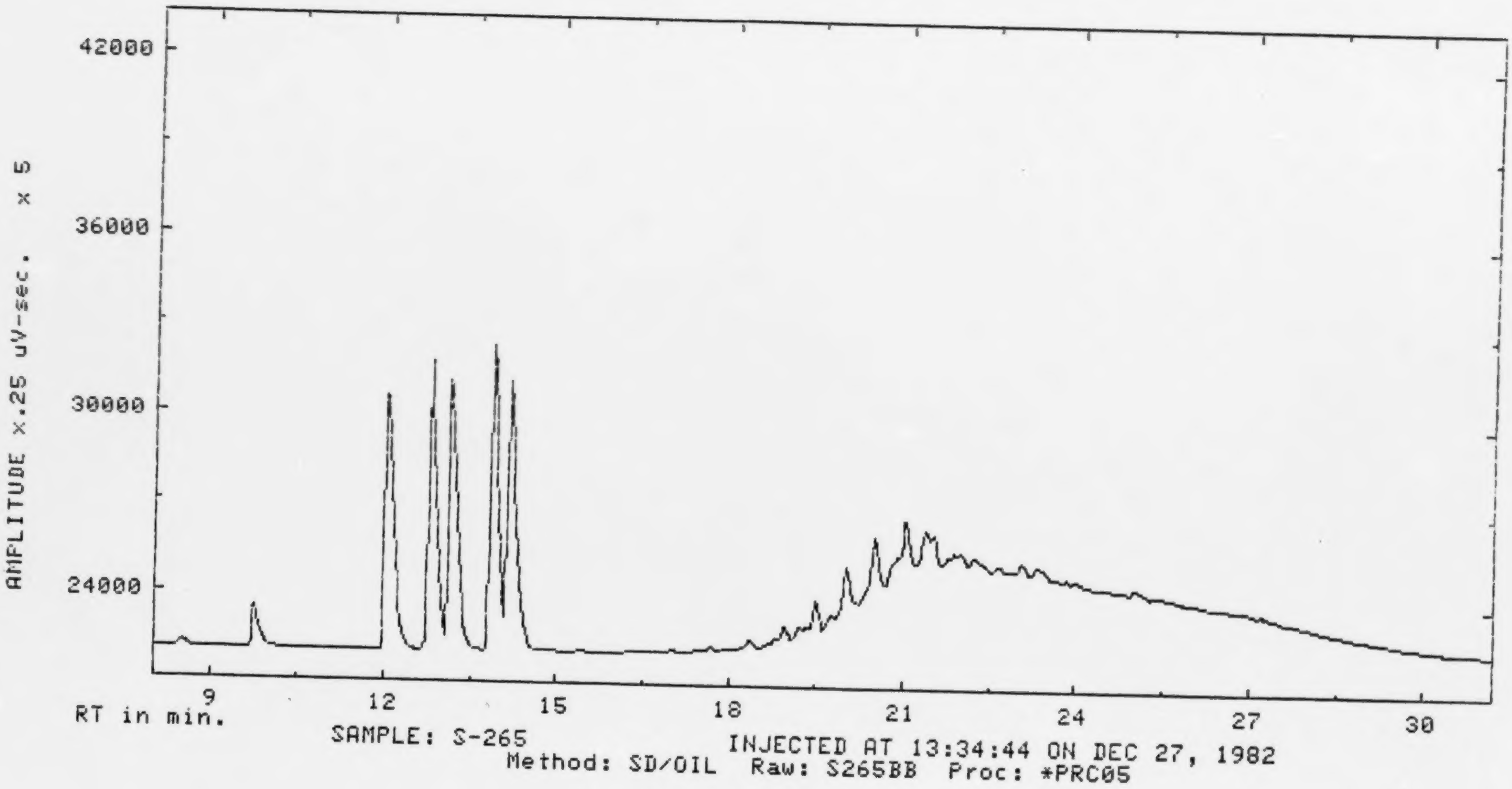

Figure C-5. Chromatogram of organic solubles from particulate matter, vehicle operated on EM-526-F fuel during FTP.

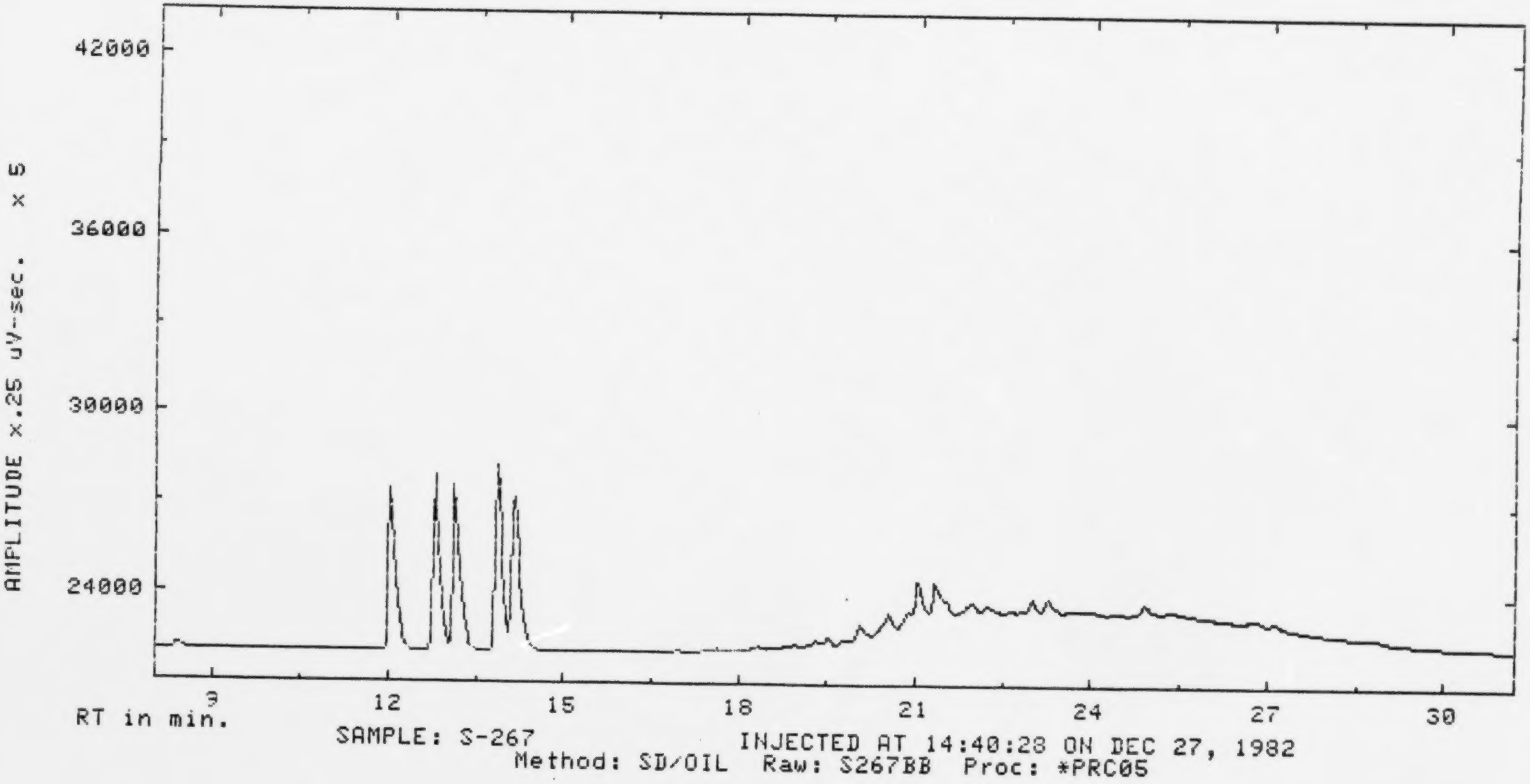

Figure C-6. Chromatogram of organic solubles from particulate matter, vehicle operated on EM-526-F fuel during HFET.

APPENDIX D

STATISTICAL ANALYSIS RESULTS

SOUTHWEST RESEARCH INSTITUTE

INTER-DEPARTMENTAL MEMORANDUM

October 4, 1982

TO: Bruce Bykowski

FROM: R.L. Mason

SUBJECT: Response to 05-6619-005 Task Order

The analysis approach proposed for meeting the objectives of the current task order is discussed in the following paragraphs. Attempts have been made to strengthen the statistical arguments while minimizing the number of assumptions and maximizing the application of the conclusions.

Experiments involving the study of the relationships between exhaust emissions and fuel properties are known to depend on several factors. These include, as a minimum, the vehicle on which the tests are run, the type of fuel, the test cycle, and the measurement techniques. Further, it is well known that the quantity of a given exhaust emission depends on a variety of fuel properties and that this type of an association precludes simple one-to-one relationships between a given emission and a specific fuel property.

The above facts have an important effect in any effort aimed at combining various studies on emissions. First, these studies most probably will have varying experimental conditions resulting in experiments utilizing different vehicles, fuels, test cycles and measurement techniques. Second, each experiment may yield differing prediction equations relating emissions to fuel properties. These equations will be based on different sample sizes as well as experimental conditions. Third, the experimental results will have wide variation as a result of the many sources of variation. This will result in differing levels of fit with some prediction equations yielding large correlation coefficients while others yield moderate-to-low correlations.

Any analysis plan devised for combining the data from many studies on petroleum-based fuels will be, at best, descriptive in nature as a result of the previous arguments. Nevertheless, it is possible to obtain some helpful information by the usage of both graphical displays of the data as well as some simple statistical techniques. The proposed method involves reviewing each study concerned with predicting emission trends from petroleum-based fuels and determining which indicate similar relationships.

Due to the difficulties involved in displaying and comparing multiple-variable equations, the primary effort in this task will be devoted to studying one-to-one relationships between exhaust emissions and fuel properties. However, if enough data are available, some effort may be given to expanding the analysis plan to consider multivariable relationships.

Since each experiment may be using different data ranges for the fuel properties (e.g., due to differing fuel types or test vehicles), the data from each study as well as from the alternate-source fuel study must be normalized to a common point. This will yield more meaningful comparisons. Hence, the data from each study will be normalized to a predetermined fuel property level (e.g., 30% aromatics).

Three procedures will be used to analyze the normalized data. These include the following:

1. Graphical Comparison

The normalized data from each study will be plotted on a graph of the emission of interest versus a specific fuel property. In this manner a region of interest will be established within which will lie the data from all petroleum-based studies. The normalized data from the alternate-source fuel will be plotted on the same graph to determine if the data fall inside or outside the region of interest.

2. Curve-Fitting Comparison

The normalized emissions data from each study will be fitted with a least squares regression line using a specified fuel property as the predictor variable. Similarly an equation will be used to fit the alternate-fuel data. These lines will be plotted on a graph similar to the one given as an example in Figure 1. The lines from the petroleum-fuel data will form a region representing the dispersion for such studies. The effects of using alternate-source fuels can be determined by observing where the alternate-source fuel line falls relative to the petroleum-based fuel band.

3. Average Comparison

Although the prediction equations obtained in step 2 will be based on varying experimental conditions and sample sizes, and will have differing degrees of fit (i.e., correlation coefficients), an attempt will be made to fit all the petroleum-based fuel data using a single regression line. This combined equation then could be used as a comparison for the alternate-source fuel fit. One means of accomplishing this analysis is to form an "average" line whose intercept and slope are the average of the intercepts and slopes, respectively, of the individual lines. Another approach might be to fit all the petroleum-data to a single line; however, this method would give undue emphasis to studies with better fits and more data. The resulting "average" fit could be used with the fuel property data from the alternate-source study to obtain predicted emission values that could be compared to the observed emission data from the alternate-source study.

This comparison would be accomplished using a goodness-of-fit statistic such as

$$X^2 = \sum_{i=1}^{n} \frac{(\text{Observed} - \text{Predicted})^2}{\text{Predicted}}$$

While X^2 is not a chi-square statistic (as would occur in a single experiment with random observations) it is similar to it and the chi-square table can be used to provide guidelines for determining whether the observed and predicted values differ.

A brief example of a typical plot of the data resulting from the above study is shown in Figure 1.

It shows that the alternate-source study's effect of aromatics is greater than the average of all petroleum-based studies reviewed. The alternate-source study's fuel aromatic contents could be inserted into the linear equation for the average of studies A, B, C, D to yield particulate emissions as if the alternate fuels were petroleum-based fuels. The predicted particulate values could be compared to actual observed particulate emissions. Where appropriate, additional comparisons would be made between the alternate-source study and individual studies. For example, if study "A" represented results from a petroleum-based study which incorporated the same vehicle type and driving cycle as the alternate-source study, then the results would indicate that the alternate-source fuels exhibit less of a particulate emission increase as compared with the petroleum-based fuels.

The previous discussions describe the statistical approach for combining the data from the various studies and the expected output from the analysis. In summary, descriptive statistical techniques based on plotting the data and fitting curves to the data will be utilized in order to compare the effects of petroleum-based fuels on exhaust emissions to those of alternate-source fuels on emissions.

The proposed methodology has some severe limitations which restrict the application of more advanced statistical concepts. These include the usage of experiments performed at differing times under differing test conditions and with differing objectives. Due to these facets, it is expected that only some general trend information will be available at the conclusion of this project.

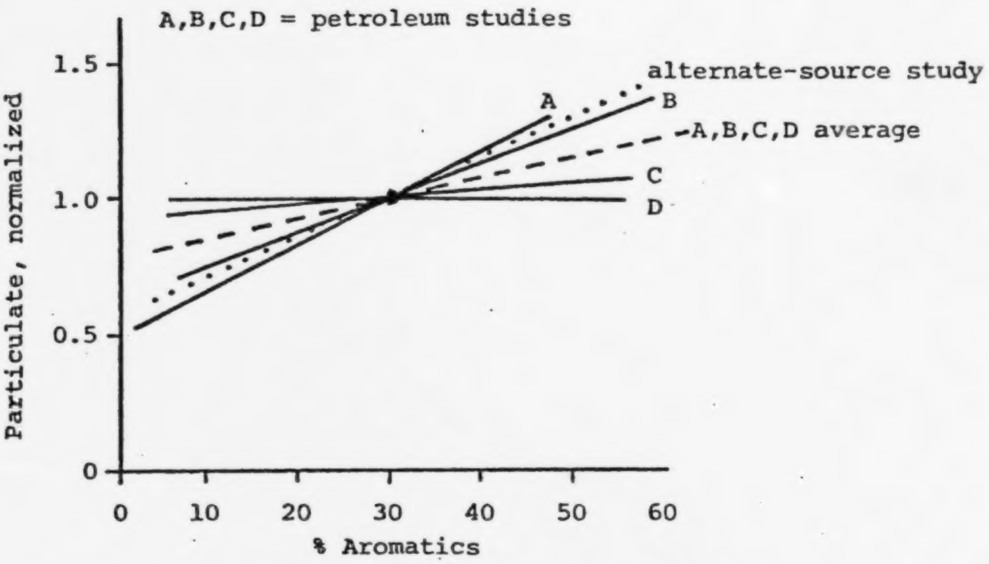

Figure 1. Particulate index vs. percent aromatics

STUDY INFO	ID	FUEL CODE	CETANE NO.	DENSITY G/ML	N PPM	ARO. VOL %	OLE. VOL %	10%PT DEG C	90%PT DEG C	HC G/KM	CO G/KM	NOX G/KM	PART. G/KM	FUEL L/100KM	BAP UG/KM	ALDE. MG/KM	PHEN. MG/KM	SOLUBLE MG/KM
A1	1.	395.	62.	0.793	1.	5.8	1.5	211.	224.	0.09	0.52	0.75	0.171	9.46	0.59	0.31	1.69	27.0
A1	1.	401.	55.	0.800	1.	2.7	1.9	206.	239.	0.11	0.50	0.85	0.151	9.55	0.42	4.89	0.00	23.7
A1	1.	404.	62.	0.794	479.	6.1	1.5	211.	224.	0.08	0.47	0.76	0.162	9.50	0.25	0.30	4.33	21.7
A1	1.	405.	61.	0.795	930.	6.6	1.5	210.	224.	0.08	0.46	0.89	0.162	9.59	0.35	15.2	29.4	17.0
A1	1.	430.	63.	0.796	493.	8.8	1.8	210.	228.	0.09	0.52	0.84	0.180	9.76	0.96	0.00	128.	22.9
A1	1.	434.	44.	0.825	5.	31.5	2.9	206.	234.	0.12	0.59	0.88	0.212	9.52	0.37	2.80	0.66	27.6
A1	1.	438.	64.	0.793	1.	6.8	6.6	210.	224.	0.09	0.48	0.85	0.155	9.84	0.21	0.00	0.17	28.4
A1	1.	448.	56.	0.783	1.	4.9	1.8	189.	223.	0.11	0.48	0.82	0.142	9.51	0.51	8.18	0.21	26.7
A1	1.	460.	46.	0.815	1.	32.1	1.0	209.	224.	0.13	0.60	0.92	0.219	9.56	0.73	0.00	1.30	30.2
A1	1.	461.	68.	0.791	1.	5.1	1.0	216.	251.	0.08	0.47	0.86	0.159	9.63	0.43	8.83	0.55	26.2
A1	1.	463.	60.	0.826	718.	30.8	1.2	206.	234.	0.13	0.66	1.04	0.287	9.62	0.43	0.00	0.18	34.7
B1	2.	238.	53.	0.845	50.	29.8	1.6	213.	313.	0.12	0.57	0.78	0.329	8.48	0.39	16.9	----	36.7
B1	2.	239	47.	0.844	50.	21.6	0.8	216.	303.	0.19	0.64	0.79	0.314	8.60	0.46	15.9	----	30.6
B1	2.	240.	47.	0.806	60.	13.0	3.4	181.	238.	0.09	0.57	0.73	0.235	8.51	0.32	16.0	----	28.3
B1	2.	241.	41.	0.861	240.	34.6	1.0	216.	301.	0.20	0.71	0.88	0.380	9.38	0.62	23.9	----	28.7
B1	2.	242.	50.	0.831	80.	12.4	0.8	213.	310.	0.12	0.68	0.85	0.292	9.38	0.23	16.9	----	26.1
B2	3.	238.	53.	0.845	50.	29.8	1.6	213.	313.	0.18	0.49	0.59	0.225	5.71	1.13	28.7	----	24.4
B2	3.	239.	47.	0.844	50.	21.6	0.8	216.	303.	0.20	0.51	0.65	0.218	5.60	1.33	12.6	----	28.8
B2	3.	240.	47.	0.806	60.	13.0	3.4	181.	238.	0.17	0.55	0.57	0.177	5.71	1.18	18.0	----	26.6
B2	3.	241.	41.	0.861	240.	34.6	1.0	216.	301.	0.71	0.81	0.58	0.375	6.17	3.64	52.5	----	58.4
B2	3.	242.	50.	0.831	80.	12.4	0.8	213.	310.	0.20	0.52	0.63	0.194	5.89	1.05	13.4	----	26.4
C1	4.	1.	47.	0.806	----	13.0	3.4	181.	238.	0.21	0.80	1.12	0.231	7.99	0.96	22.6	----	71.6
C1	4.	2.	47.	0.832	----	27.0	1.8	204.	280.	0.19	0.78	1.14	0.308	8.34	----	24.2	----	----
C1	4.	3.	49.	0.844	----	21.6	0.8	216.	303.	0.29	0.88	1.64	0.247	8.87	----	37.4	----	----
C1	4.	4.	49.	0.843	----	26.5	0.9	214.	306.	0.30	0.90	1.43	0.316	8.89	0.98	34.7	----	74.0
D1	5.	20.	50.	0.850	----	35.1	0.0	223.	316.	0.15	0.68	0.85	0.172	8.06	----	31.1	----	----
D1	5.	2.	47.	0.847	----	28.8	1.4	217.	309.	0.21	0.84	0.83	0.187	7.71	----	29.6	----	----
D1	5.	1.	48.	0.835	----	22.8	1.1	205.	297.	0.26	0.88	0.81	0.178	7.79	----	23.0	----	----
F1	6.	1.	48.4	0.829	----	23.7	0.96	197.	290.	0.31	0.71	0.46	----	4.97	----	----	----	----
F1	6.	4.	50.0	0.809	----	19.2	0.70	151.	303.	0.37	0.74	0.46	----	5.16	----	----	----	----
F1	6.	5.	43.5	0.840	----	36.9	0.72	139.	308.	1.74	1.50	0.38	----	5.05	----	----	----	----
F1	6.	6.	----	0.800	----	19.2	0.72	136.	279.	----	0.87	0.40	----	5.29	----	----	----	----
F2	7.	1.	48.4	0.829	----	23.7	0.96	197.	290.	0.55	1.23	0.96	----	12.32	----	----	----	----
F2	7.	5.	43.5	0.840	----	36.9	0.72	139.	308.	0.30	1.17	1.12	----	12.99	----	----	----	----
F2	7.	6.	----	0.800	----	19.2	0.72	136.	279.	0.29	1.08	0.96	----	12.38	----	----	----	----
G1	8.	7812.	61.0	0.784	----	0.0	----	209.	247.	----	----	----	----	----	----	----	----	----
G1	8.	7938.	45.7	0.810	----	13.0	----	206.	226.	----	----	----	----	----	----	----	----	----
G1	8.	7941.	47.7	0.820	----	13.0	----	213.	309.	0.1	0.4	1.0	0.11	10.7	----	----	----	19.3
G1	8.	8017.	44.9	0.811	----	17.0	----	188.	244.	----	----	----	----	----	----	----	----	----
G1	8.	7939.	41.2	0.823	----	20.0	----	203.	249.	0.1	0.4	1.1	0.14	11.2	----	----	----	31.7
G1	8.	7942.	41.1	0.819	----	20.0	----	201.	227.	0.1	0.4	0.9	0.11	9.8	----	----	----	25.5
G1	8.	7926.	44.2	0.852	----	32.0	----	214.	306.	0.1	0.5	1.0	0.12	10.2	----	----	----	39.8
G1	8.	7943.	39.8	0.835	----	32.0	----	199.	312.	0.2	0.6	0.9	0.11	10.2	----	----	----	19.3
G1	8.	7940.	37.0	0.830	----	34.0	----	199.	251.	0.1	0.5	0.9	0.11	9.8	----	----	----	31.7
G2	9.	7812.	61.0	0.784	----	0.0	----	209.	247.	0.7	1.2	0.9	0.10	----	----	----	----	39.8
G2	9.	7938.	45.7	0.810	----	13.0	----	206.	226.	0.1	0.5	0.7	0.14	11.2	----	----	----	41.0
G2	9.	7941.	47.7	0.820	----	13.0	----	213.	309.	0.1	0.6	0.8	0.15	11.8	----	----	----	44.7
G2	9.	8017.	44.9	0.811	----	17.0	----	188.	244.	0.2	0.7	0.9	0.12	----	----	----	----	31.1
G2	9.	7939.	41.2	0.823	----	20.0	----	203.	249.	0.1	0.6	0.8	0.13	11.	----	----	----	32.9
G2	9.	7942.	41.4	0.819	----	20.0	----	201.	227.	0.1	0.6	0.8	0.14	13.1	----	----	----	57.2
G2	9.	7926.	44.2	0.852	----	32.0	----	214.	306.	0.2	0.9	0.9	0.19	11.8	----	----	----	40.4
G2	9.	7943.	39.8	0.835	----	32.0	----	199.	312.	0.2	0.6	0.8	0.14	11.2	----	----	----	29.8
G2	9.	7940.	37.0	0.830	----	34.0	----	199.	251.	0.2	0.7	0.8	0.16	11.2	----	----	----	34.2
H1	10.	2.	27.	0.707	----	7.0	4.0	54.	130.		----				----	----	----	61.4
H1	10.	3.	45.	0.707	----	7.0	4.0	54.	130.		----				----	----	----	30.3
H1	10.	6.	28.	0.678	----	3.0	3.0	63.	92.		----				----	----	----	48.9
H1	10.	7.	47.	0.678	----	3.0	3.0	63.	92.		----				----	----	----	24.8
H1	10.	9.	28.	0.723	----	6.0	1.0	79.	122.		----				----	----	----	45.5
H1	10.	11.	49.	0.817	----	17.0	4.0	201.	255.		----				----	----	----	20.1
H1	10.	13.	39.	0.789	----	13.0	2.0	165.	186.		----				----	----	----	39.7

STUDY INFO	ID	FUEL CODE	CETANE NO.	DENSITY G/ML	N PPM	ARO. VOL %	OLE. VOL %	10%PT DEG C	90%PT DEG C	HC G/KM	CO G/KM	NOX G/KM	PART. G/KM	FUEL L/100KM	BAP UG/KM	ALDE. MG/KM	PHEN. MG/KM	SOLUBLE MG/KM
H1	10.	15.	41.	0.786	----	14.0	1.0	125.	235.		----				----	----	----	
H1	10.	16.	42.	0.826	----	28.0	2.0	133.	308.		----				----	----	----	
H1	10.	17.	40.	0.879	----	46.0	1.0	267.	320.		----				----	----	----	
H1	10.	18.	46.	0.816	----	19.0	2.0	143.	309.		----				----	----	----	
H1	10.	19.	52.	0.834	----	23.0	4.0	219.	314.		----				----	----	----	
H1	10.	20.	47.	0.845	----	35.0	3.0	198.	296.		----				----	----	----	
H1	10.	21.	50.	0.851	----	35.0	2.0	222.	314.		----				----	----	----	
H1	10.	22.	43.	0.845	----	34.0	3.0	203.	297.		----				----	----	----	
H1	10.	23.	47.	0.851	----	35.0	5.0	221.	314.		----				----	----	----	
H1	10.	24.	43.	0.848	----	33.0	3.0	213.	307.		----				----	----	----	
H1	10.	25.	47.	0.840	----	28.0	3.0	214.	311.		----				----	----	----	
H1	10.	26.	47.	0.813	----	17.0	3.0	190.	247.		----				----	----	----	
H1	10.	27.	54.	0.754	----	7.0	.0	101.	233.		----				----	----	----	
H1	10.	28.	45.	0.843	----	28.0	4.0	222.	303.		----				----	----	----	
H1	10.	30.	31.	0.759	----	13.0	1.0	85.	208.		----				----	----	----	
H1	10.	31.	54.	0.776	----	11.0	1.0	117.	246.		----				----	----	----	
H1	10.	32.	44.	0.864	----	40.0	3.0	233.	311.		----				----	----	----	
H1	10.	33.	50.	0.832	----	24.0	3.0	204.	309.		----				----	----	----	
H1	10.	34.	47.	0.759	----	13.0	1.0	85.	208.		----				----	----	----	
H1	10.	35.	47.	0.789	----	13.0	2.0	165.	186.		----				----	----	----	
H1	10.	36.	47.	0.737	----	14.0	1.0	79.	145.		----				----	----	----	
H1	10.	40.	36.	0.780	----	2.0	2.0	215.	233.		----				----	----	----	
H1	10.	43.	52.	0.849	----	19.0	----	221.	358.		----				----	----	----	
H1	10.	46.	80.	0.840	----	0.1	----	190.	320.		----				----	----	----	
I1	11.	1.	51.0	0.809	----	19.9	----	197.	256.	----	----	----	0.298	----	----	----	----	62.2
I1	11.	2.	48.0	0.851	----	32.7	----	209.	317.	----	----	----	0.435	----	----	----	----	93.2
I1	11.	3.	52.2	0.864	----	20.8	----	262.	364.	----	----	----	0.635	----	----	----	----	311.
I1	11.	4.	45.3	0.883	----	33.7	----	271.	363.	----	----	----	0.827	----	----	----	----	360.
I1	11.	5.	47.7	0.871	----	32.1	----	254.	349.	----	----	----	0.634	----	----	----	----	193.
I1	11.	6.	40.5	0.899	----	47.0	----	261.	364.	----	----	----	0.914	----	----	----	----	342.
I1	11.	7.	48.2	0.843	----	9.7	----	258.	354.	----	----	----	0.392	----	----	----	----	130.
I1	11.	8.	32.6	0.918	----	57.7	----	254.	367.	----	----	----	0.988	----	----	----	----	447.
I1	11.	9.	40.0	0.775	----	12.4	----	112.	224.	----	----	----	0.292	----	----	----	----	53.4
I1	11.	10.	28.0	0.872	----	57.7	----	177.	346.	----	----	----	0.914	----	----	----	----	255.
I1	11.	11.	29.0	0.782	----	1.7	----	211.	246.	----	----	----	0.193	----	----	----	----	35.4
I1	11.	12.	71.1	0.829	----	0.3	----	309.	365.	----	----	----	0.348	----	----	----	----	140.
I1	11.	13.	46.0	0.795	----	0.0	----	221.	342.	----	----	----	0.261	----	----	----	----	116.
I1	11.	14.	52.6	0.808	----	0.0	----	231.	357.	----	----	----	0.305	----	----	----	----	117.
I1	11.	15.	32.0	0.872	----	45.1	----	191.	328.	----	----	----	0.566	----	----	----	----	150.
I2	12.	1.	51.0	0.809	----	19.9	----	197.	256.	----	----	----	0.242	----	----	----	----	31.1
I2	12.	2.	48.0	0.851	----	32.7	----	209.	317.	----	----	----	0.311	----	----	----	----	61.5
I2	12.	4.	45.3	0.883	----	33.7	----	271.	363.	----	----	----	0.423	----	----	----	----	154.
I2	12.	7.	48.2	0.843	----	9.7	----	258.	354.	----	----	----	0.242	----	----	----	----	64.6
I2	12.	11.	29.0	0.782	----	1.7	----	211.	246.	----	----	----	0.155	----	----	----	----	29.2
I2	12.	13.	46.0	0.795	----	0.0	----	221.	342.	----	----	----	0.174	----	----	----	----	41.6
I2	12.	1.	51.0	0.809	----	19.9	----	197.	256.	----	----	----	0.143	----	----	----	----	60.9
I2	12.	2.	48.0	0.851	----	32.7	----	209.	317.	----	----	----	0.180	----	----	----	----	62.8
I2	12.	8.	32.6	0.918	----	57.7	----	254.	367.	----	----	----	0.329	----	----	----	----	204.
I2	12.	11.	29.0	0.782	----	1.7	----	211.	246.	----	----	----	0.081	----	----	----	----	44.7
I2	12.	12.	71.1	0.829	----	0.3	----	309.	365.	----	----	----	0.118	----	----	----	----	71.5
I2	12.	15.	32.0	0.872	----	45.1	----	191.	328.	----	----	----	0.224	----	----	----	----	122.
I2	12.	1.	51.0	0.809	----	19.9	----	197.	256.	----	----	----	0.267	----	----	----	----	46.0
I2	12.	2.	48.0	0.851	----	32.7	----	209.	317.	----	----	----	0.323	----	----	----	----	50.3
I2	12.	4.	45.3	0.883	----	33.7	----	271.	363.	----	----	----	0.329	----	----	----	----	64.6
I2	12.	11.	29.0	0.782	----	1.7	----	211.	246.	----	----	----	0.174	----	----	----	----	36.7
I2	12.	12.	71.1	0.829	----	0.3	----	309.	365.	----	----	----	0.174	----	----	----	----	39.2
J1	13.	329.	50.1	0.837	48.	21.3	1.7	219.	219.	0.31	1.03	0.82	0.255	8.52	2.0	12.0	8.0	140.
J1	13.	469.	48.0	0.849	----	39.1	0.9	307.	315.	0.35	1.18	0.87	0.280	8.59	1.1	10.9	15.7	156.
J2	14.	329.	50.1	0.837	48.	21.3	1.7	219.	219.	0.24	0.84	1.27	0.162	10.36	1.1	9.3	26.7	60.2
J2	14.	469.	48.0	0.849	----	39.1	0.9	307.	315.	0.30	0.98	1.26	0.205	10.23	3.4	5.2	8.8	88.5

STUDY INFO	ID	FUEL CODE	CETANE NO.	DENSITY G/ML	N PPM	ARO. VOL %	OLE. VOL %	10%PT DEG C	90%PT DEG C	HC G/KM	CO G/KM	NOX G/KM	PART. G/KM	FUEL L/100KM	BAP UG/KM	ALDE. MG/KM	PHEN. MG/KM	SOLUBLE MG/KM
J3	15.	329.	50.1	0.837	48.	21.3	1.7	219.	219.	0.12	0.65	0.64	0.236	10.69	0.3	1.1	8.5	28.2
J3	15.	469.	48.0	0.849	----	39.1	0.9	307.	315.	0.13	0.69	0.65	0.273	10.64	0.5	0.5	9.7	37.1
K1	16.	329.	50.	0.837	48.	21.3	1.7	219.	302.	0.31	0.96	0.66	0.249	6.37	14.9	14.	12.	44.8
K1	16.	453.	49.	0.835	5.	28.5	2.1	236.	295.	0.31	1.06	0.67	0.274	6.63	34.0	9.	11.	48.6
K1	16.	473.	45.	0.808	1.	22.0	2.0	189.	228.	0.38	1.20	0.70	0.250	6.62	31.6	13.	0.5	30.4
K1	16.	474.	42.	0.870	1600.	34.9	1.4	234.	330.	0.39	1.21	0.83	0.321	6.23	44.1	8.	14.	56.6
K1	16.	476.	35.	0.806	1000.	16.2	0.0	53.	303.	0.68	1.38	0.65	0.208	6.64	30.2	12.	2.	52.4
K1	16.	478.	38.	0.867	2000.	39.9	1.2	209.	303.	0.60	1.31	0.76	0.394	6.45	10.0	2.	12.	101.
K1	16.	482.	44.	0.856	267.	36.4	0.0	207.	316.	0.33	1.14	0.73	0.281	6.11	24.3	3.	24.	36.7
K1	16.	485.	45.	0.833	142.	25.5	0.5	157.	302.	0.34	1.16	0.76	0.299	6.59	8.7	----	----	----
K1	16.	527.	50.	0.804	1.	24.0	0.0	200.	392.	0.32	1.08	0.64	0.221	6.35	19.6	2.	0.0	43.3
K1	16.	526.	42.	0.861	980.	37.2	1.2	212.	316.	0.36	1.12	0.71	0.282	6.18	19.0	0.0	0.0	47.8

STUDY INFO	ID	FUEL CODE	DENSITY G/ML	HC NORM	NOX NORM	PART. NORM	FUEL NORM
A1	1.	395.	.793	.5960	.7123	.5498	.9895
A1	1.	401.	.800	.7285	.8072	.4855	.9990
A1	1.	404.	.794	.5298	.7217	.5209	.9937
A1	1.	405.	.795	.5298	.8452	.5209	1.0031
A1	1.	430.	.796	.5960	.7977	.5788	1.0209
A1	1.	434.	.825	.7947	.8357	.6817	.9958
A1	1.	438.	.793	.5960	.8072	.4984	1.0293
A1	1.	448.	.783	.7285	.7787	.4566	.9948
A1	1.	460.	.815	.8609	.8737	.7042	1.0000
A1	1.	461.	.791	.5298	.8167	.5113	1.0073
A1	1.	463.	.826	.8609	.9877	.9228	1.0063
B1	2.	238.	.845	.7101	1.2601	.9620	.9438
B1	2.	2390.	.844	1.1243	1.2763	.9181	.9572
B1	2.	240.	.806	.5325	1.1793	.6871	.9471
B1	2.	241.	.861	1.1834	1.4216	1.1111	1.0440
B1	2.	242.	.831	.7101	1.3732	.8538	1.0440
B2	3.	238.	.845	.4639	.9704	.8123	.9706
B2	3.	239.	.844	.5155	1.0691	.7870	.9519
B2	3.	240.	.806	.4381	.9375	.6390	.9706
B2	3.	241.	.861	1.8299	.9539	1.3538	1.0488
B2	3.	242.	.831	.5155	1.0362	.7004	1.0012
C1	4.	1.	.806	.7292	.7292	.7700	.8919
C1	4.	2.	.832	.6597	.7422	1.0267	.9310
C1	4.	3.	.844	1.0069	1.0677	.8233	.9902
C1	4.	4.	.843	1.0417	.9310	1.0533	.9924
D1	5.	20.	.850	.8876	1.0071	.9609	1.0181
D1	5.	2.	.847	1.2426	.9834	1.0447	.9739
D1	5.	1.	.835	1.5385	.9597	.9944	.9840
F1	6.	1.	.829	.1800	1.1192	----	1.0106
F1	6.	4.	.809	.2149	1.1192	----	1.0492
F1	6.	5.	.840	1.0105	.9246	----	1.0268
F1	6.	6.	.800	----	.9732	----	1.0756
F2	7.	1.	.829	1.2673	.8735	----	.9567
F2	7.	5.	.840	.6912	1.0191	----	1.0088
F2	7.	6.	.800	.6682	.8735	----	.9614
G1	8.	7812.	.784	----	----	----	----
G1	8.	7938.	.810	----	----	----	----
G1	8.	7941.	.820	.7692	1.0384	.9402	1.0568
G1	8.	8017.	.811	----	----	----	----
G1	8.	7939.	.823	.7692	1.1423	1.1966	1.1062
G1	8.	7942.	.819	.7692	.9346	.9402	.9679
G1	8.	7926.	.852	.7692	1.0384	1.0256	1.0074
G1	8.	7943.	.835	1.5385	.9346	.9402	1.0074
G1	8.	7940.	.830	.7692	.9346	.9402	.9679
G2	9.	7812.	.784	21.2121	1.1002	.5682	----
G2	9.	7938.	.810	3.0303	.8557	.7955	.9695
G2	9.	7941.	.820	3.0303	.9780	.8523	1.0215
G2	9.	8017.	.811	6.0606	1.1002	.6818	----
G2	9.	7939.	.823	3.0303	.9780	.7386	.9695
G2	9.	7942.	.819	3.0303	.9780	.7955	1.1340
G2	9.	7926.	.852	6.0606	1.1002	1.0795	1.0215
G2	9.	7943.	.835	6.0606	.9780	.7955	.9695
G2	9.	7940.	.830	6.0606	.9780	.9091	.9695

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 STUDY    FUEL          DENSITY                                     HC          NOX   PART.  FUEL
INFO ID   CODE            G/ML                                     NORM         NORM  NORM   NORM
---- ---  ----  ------  -------  ----  -----  -----  -----  -----  ----  ----  ----  ----  -------  -----  -----  -----  -----
H1   10.    2.             .707                                   4.7196       1.4413  .5592  .9782
H1   10.    3.             .707                                   2.1729       1.0401  .9174  .9852
H1   10.    6.             .678                                   4.5561        .9609  .5894  .9961
H1   10.    7.             .678                                   1.9626        .9014  .8365  .9571
H1   10.    9.             .723                                   1.1682       1.1194  .9129  .9439
H1   10.   11.             .817                                    .1636        .8370 1.1048  .9727
H1   10.   13.             .789                                    .1636        .7033 1.0172  .9127
H1   10.   15.             .786                                   4.0421        .9212  .6250  .9883
H1   10.   16.             .826                                   1.0981       1.2729  .9371  .9922
H1   10.   17.             .879                                    .8879       1.3422 1.1502 1.0078
H1   10.   18.             .816                                   2.8037       1.0253 1.1093 1.0023
H1   10.   19.             .834                                   1.1682       1.0599  .9378 1.1403
H1   10.   20.             .845                                   2.5935       1.1441  .8826  .9758
H1   10.   21.             .851                                   1.7290       1.0599  .9892  .9260
H1   10.   22.             .845                                   1.1916       1.0203  .7481  .9712
H1   10.   23.             .851                                    .3738       1.1095  .9091  .9673
H1   10.   24.             .848                                    .4206        .9559  .8698  .9478
H1   10.   25.             .840                                    .2804       1.0599  .8501  .9906
H1   10.   26.             .813                                    .1168        .9856  .8932  .9049
H1   10.   27.             .754                                    .2804        .8470  .8600  .8527
H1   10.   28.             .843                                    .3505        .9312 1.1955 1.0585
H1   10.   30.             .759                                  32.5234       1.4859  .6499 1.1052
H1   10.   31.             .776                                    .7944       1.2729  .9537  .9556
H1   10.   32.             .864                                    .3037        .8321 1.0874  .9860
H1   10.   33.             .832                                    .3972       1.0550 1.0149  .9587
H1   10.   34.             .759                                    .5140       1.0797 1.1124  .9657
H1   10.   35.             .789                                    .3972       1.0451 1.1486  .9704
H1   10.   36.             .737                                    .8178       1.0896 1.0058  .9509
H1   10.   40.             .780                                    .1168        .5002  .7617  .9790
H1   10.   43.             .849                                    .6776        .6835 1.1683 1.1582
H1   10.   46.             .840                                    .2336        .8123  .8683 1.0663
I1   11.    1.             .809                                    ----         ----   .5293  ----
I1   11.    2.             .851                                    ----         ----   .7726  ----
I1   11.    3.             .864                                    ----         ----  1.1279  ----
I1   11.    4.             .883                                    ----         ----  1.4689  ----
I1   11.    5.             .871                                    ----         ----  1.1261  ----
I1   11.    6.             .899                                    ----         ----  1.6234  ----
I1   11.    7.             .843                                    ----         ----   .6963  ----
I1   11.    8.             .918                                    ----         ----  1.7549  ----
I1   11.    9.             .775                                    ----         ----   .5187  ----
I1   11.   10.             .872                                    ----         ----  1.6234  ----
I1   11.   11.             .782                                    ----         ----   .3428  ----
I1   11.   12.             .829                                    ----         ----   .6181  ----
I1   11.   13.             .795                                    ----         ----   .4636  ----
I1   11.   14.             .808                                    ----         ----   .5417  ----
I1   11.   15.             .872                                    ----         ----  1.0053  ----
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  STUDY    FUEL          DENSITY                                     HC           NOX    PART.   FUEL
INFO  ID   CODE             G/ML                                     NORM         NORM   NORM    NORM
---- ---   ----  ------  -------  ----  -----  -----  -----  -----  ----   ----  ----   ----   ------- -----  -----  -----  -----
I2   12.     1.             .809                                     ----          ----   .9490  ----
I2   12.     2.             .851                                     ----          ----  1.2196  ----
I2   12.     4.             .883                                     ----          ----  1.6588  ----
I2   12.     7.             .843                                     ----          ----   .9490  ----
I2   12.    11.             .782                                     ----          ----   .6078  ----
I2   12.    13.             .795                                     ----          ----   .6824  ----
I2   12.     1.             .809                                     ----          ----   .5608  ----
I2   12.     2.             .851                                     ----          ----   .7059  ----
I2   12.     8.             .918                                     ----          ----  1.2902  ----
I2   12.    11.             .782                                     ----          ----   .3176  ----
I2   12.    12.             .829                                     ----          ----   .4627  ----
I2   12.    15.             .872                                     ----          ----   .8784  ----
I2   12.     1.             .809                                     ----          ----  1.0471  ----
I2   12.     2.             .851                                     ----          ----  1.2667  ----
I2   12.     4.             .883                                     ----          ----  1.2902  ----
I2   12.    11.             .782                                     ----          ----   .6824  ----
I2   12.    12.             .829                                     ----          ----   .6824  ----
J1   13.   329.             .837                                    .8782         .9393   .9043   .9912
J1   13.   469.             .849                                    .9915         .9966   .9929   .9993
J2   14.   329.             .837                                    .7869        1.0087   .7751  1.0138
J2   14.   469.             .849                                    .9836        1.0008   .9809  1.0011
J3   15.   329.             .837                                    .9160         .9831   .8551  1.0051
J3   15.   469.             .849                                    .9924         .9985   .9891  1.0004
K1   16.   329.             .837                                    .7789         .9016   .8328  1.0020
K1   16.   453.             .835                                    .7789         .9153   .9164  1.0429
K1   16.   473.             .808                                    .9548         .9563   .8361  1.0414
K1   16.   474.             .870                                    .9799        1.1339  1.0736   .9800
K1   16.   476.             .806                                   1.7085         .8880   .6957  1.0445
K1   16.   478.             .867                                   1.5075        1.0383  1.3177  1.0146
K1   16.   482.             .856                                    .8291         .9973   .9398   .9611
K1   16.   485.             .833                                    .8543        1.0383  1.0000  1.0367
K1   16.   527.             .804                                    .8040         .8743   .7391   .9989
K1   16.   526.             .861                                    .9045         .9699   .9431   .9722
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STUDY INFO	ID	FUEL CODE	CETANE NO.	HC NORM	CO NORM	SOLUBLE NORM
A1	1.	395.	62.0	.7258	.9028	.9708
A1	1.	401.	55.0	.8871	.8681	.8522
A1	1.	404.	62.0	.6452	.8160	.7803
A1	1.	405.	61.0	.6452	.7986	.6113
A1	1.	430.	63.0	.7258	.9028	.8234
A1	1.	434.	44.0	.9677	1.0243	.9924
A1	1.	438.	64.0	.7258	.8333	1.0212
A1	1.	448.	56.0	.8871	.8333	.9601
A1	1.	460.	46.0	1.0484	1.0417	1.0859
A1	1.	461.	68.0	.6452	.8160	.9421
A1	1.	463.	60.0	1.0484	1.1458	1.2477
B1	2.	238.	53.0	.8108	.8920	1.2313
B1	2.	2390.	47.0	1.2838	1.0016	1.0266
B1	2.	240.	47.0	.6081	.8920	.9494
B1	2.	241.	41.0	1.3514	1.1111	.9629
B1	2.	242.	50.0	.8108	1.0642	.8756
B2	3.	238.	53.0	.5660	.8277	.7049
B2	3.	239.	47.0	.6289	.8615	.8320
B2	3.	240.	47.0	.5346	.9291	.7685
B2	3.	241.	41.0	2.2327	1.3682	1.6872
B2	3.	242.	50.0	.6289	.8784	.7627
C1	4.	1.	47.0	1.0500	1.0127	1.0000
C1	4.	2.	47.0	.9500	.9873	----
C1	4.	3.	49.0	1.4500	1.1139	----
C1	4.	4.	49.0	1.5000	1.1392	1.0335
D1	5.	20.	50.0	.6250	.7727	----
D1	5.	2.	47.0	.8750	.9545	----
D1	5.	1.	48.0	1.0833	1.0000	----
F1	6.	1.	48.4	.3543	.6947	----
F1	6.	4.	50.0	.4229	.7241	----
F1	6.	5.	43.5	1.9886	1.4677	----
F1	6.	6.	----	----	.8513	----
F2	7.	1.	48.4	1.1482	1.0140	----
F2	7.	5.	43.5	.6263	.9646	----
F2	7.	6.	----	.6054	.8904	----
G1	8.	7812.	61.0	----	----	----
G1	8.	7938.	45.7	----	----	----
G1	8.	7941.	47.7	.9901	.9569	.7399
G1	8.	8017.	44.9	----	----	----
G1	8.	7939.	41.2	.9901	.9569	1.2152
G1	8.	7942.	41.1	.9901	.9569	.9775
G1	8.	7926.	44.2	.9901	1.1962	1.5257
G1	8.	7943.	39.8	1.9802	1.4354	.7399
G1	8.	7940.	37.0	.9901	1.1962	1.2152
G2	9.	7812.	61.0	2.6923	1.5748	1.0092
G2	9.	7938.	45.7	.3846	.6562	1.0396
G2	9.	7941.	47.7	.3846	.7874	1.1334
G2	9.	8017.	44.9	.7692	.9186	.7886
G2	9.	7939.	41.2	.3846	.7874	.8342
G2	9.	7942.	41.4	.3846	.7874	1.4503
G2	9.	7926.	44.2	.7692	1.1811	1.0244
G2	9.	7943.	39.8	.7692	.7874	.7556
G2	9.	7940.	37.0	.7692	.9186	.8672

STUDY INFO	ID	FUEL CODE	CETANE NO.	HC NORM	CO NORM	SOLUBLE NORM
H1	10.	2.	27.0	2.6200	----	1.6474
H1	10.	3.	45.0	1.2062	----	.8130
H1	10.	6.	28.0	2.5292	----	1.3120
H1	10.	7.	47.0	1.0895	----	.6654
H1	10.	9.	28.0	.6485	----	1.2208
H1	10.	11.	49.0	.0908	----	.5393
H1	10.	13.	39.0	.0908	----	1.0652
H1	10.	15.	41.0	2.2438	----	1.2664
H1	10.	16.	42.0	.6096	----	1.1672
H1	10.	17.	40.0	.4929	----	.9498
H1	10.	18.	46.0	1.5564	----	.9767
H1	10.	19.	52.0	.6485	----	.5661
H1	10.	20.	47.0	1.4397	----	.6922
H1	10.	21.	50.0	.9598	----	1.2235
H1	10.	22.	43.0	.6615	----	1.3013
H1	10.	23.	47.0	.2075	----	1.1135
H1	10.	24.	43.0	.2335	----	1.2396
H1	10.	25.	47.0	.1556	----	.8666
H1	10.	26.	47.0	.0649	----	.7459
H1	10.	27.	54.0	.1556	----	1.0706
H1	10.	28.	45.0	.1946	----	----
H1	10.	30.	31.0	18.0545	----	1.2772
H1	10.	31.	54.0	.4410	----	.5849
H1	10.	32.	44.0	.1686	----	.9015
H1	10.	33.	50.0	.2205	----	.8318
H1	10.	34.	47.0	.2853	----	.9257
H1	10.	35.	47.0	.2205	----	.7513
H1	10.	36.	47.0	.4540	----	1.3255
H1	10.	40.	36.0	.0649	----	----
H1	10.	43.	52.0	.3761	----	.9606
H1	10.	46.	80.0	.1297	----	1.4060
I1	11.	1.	51.0	----	----	.3428
I1	11.	2.	48.0	----	----	.5136
I1	11.	3.	52.2	----	----	1.7138
I1	11.	4.	45.3	----	----	1.9838
I1	11.	5.	47.7	----	----	1.0635
I1	11.	6.	40.5	----	----	1.8846
I1	11.	7.	48.2	----	----	.7164
I1	11.	8.	32.6	----	----	2.4632
I1	11.	9.	40.0	----	----	.2943
I1	11.	10.	28.0	----	----	1.4052
I1	11.	11.	29.0	----	----	.1951
I1	11.	12.	71.1	----	----	.7715
I1	11.	13.	46.0	----	----	.6392
I1	11.	14.	52.6	----	----	.6447
I1	11.	15.	32.0	----	----	.8266

```
 STUDY    FUEL   CETANE
INFO ID   CODE    NO.                                               HC      CO                                        SOLUBLE
---- ---  ----  ------  ------- ---- ----- ----- ----- -----      NORM    NORM   ---- ---- ------ ----- ----- -----    NORM
                                                                   ----    ----                                        -----
I2   12.    1.    51.0                                             ----    ----                                        .4534
I2   12.    2.    48.0                                             ----    ----                                        .8966
I2   12.    4.    45.3                                             ----    ----                                       2.2452
I2   12.    7.    48.2                                             ----    ----                                        .9418
I2   12.   11.    29.0                                             ----    ----                                        .4257
I2   12.   13.    46.0                                             ----    ----                                        .6065
I2   12.    1.    51.0                                             ----    ----                                        .8879
I2   12.    2.    48.0                                             ----    ----                                        .9156
I2   12.    8.    32.6                                             ----    ----                                       2.9742
I2   12.   11.    29.0                                             ----    ----                                        .6517
I2   12.   12.    71.1                                             ----    ----                                       1.0424
I2   12.   15.    32.0                                             ----    ----                                       1.7787
I2   12.    1.    51.0                                             ----    ----                                        .6707
I2   12.    2.    48.0                                             ----    ----                                        .7333
I2   12.    4.    45.3                                             ----    ----                                        .9418
I2   12.   11.    29.0                                             ----    ----                                        .5351
I2   12.   12.    71.1                                             ----    ----                                        .5715
J1   13.  329.    50.1                                             .8401   .8233                                       .8556
J1   13.  469.    48.0                                             .9485   .9432                                       .9534
J2   14.  329.    50.1                                             .7295   .8023                                       .5903
J2   14.  469.    48.0                                             .9119   .9360                                       .8679
J3   15.  329.    50.1                                             .8889   .9168                                       .6822
J3   15.  469.    48.0                                             .9630   .9732                                       .8975
K1   16.  329.    50.0                                             .9309   .8767                                       .9902
K1   16.  453.    49.0                                             .9309   .9680                                      1.0742
K1   16.  473.    45.0                                            1.1411  1.0959                                       .6719
K1   16.  474.    42.0                                            1.1712  1.1050                                      1.2510
K1   16.  476.    35.0                                            2.0420  1.2603                                      1.1582
K1   16.  478.    38.0                                            1.8018  1.1963                                      2.2323
K1   16.  482.    44.0                                             .9910  1.0411                                       .8112
K1   16.  485.    45.0                                            1.0210  1.0594                                       ----
K1   16.  527.    50.0                                             .9610   .9863                                       .9570
K1   16.  526.    42.0                                            1.0811  1.0228                                      1.0565
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   STUDY    FUEL                       N
INFO  ID    CODE                      PPM                                  CO                          BAP            SOLUBLE
---- ---    ----  ------  -------   ------  ---  -----  -----  -----  ---- NORM                        NORM              NORM
                                                                          -------  --  ----  -------  -------  ---  -----  -------
 A1     1.   395.                      1.                                  .9981                      1.2292           1.0092
 A1     1.   401.                      1.                                  .9597                       .8750            .8859
 A1     1.   404.                    479.                                  .9021                       .5208            .8111
 A1     1.   405.                    930.                                  .8829                       .7292            .6354
 A1     1.   430.                    493.                                  .9981                      2.0000            .8560
 A1     1.   434.                      5.                                 1.1324                       .7708           1.0317
 A1     1.   438.                      1.                                  .9213                       .4375           1.0616
 A1     1.   448.                      1.                                  .9213                      1.0625            .9980
 A1     1.   460.                      1.                                 1.1516                      1.5208           1.1288
 A1     1.   461.                      1.                                  .9021                       .8958            .9793
 A1     1.   463.                    718.                                 1.2668                       .8958           1.2971
 B1     2.   238.                     50.                                  .9120                      1.0183           1.2104
 B1     2.  2390.                     50.                                 1.0240                      1.2010           1.0092
 B1     2.   240.                     60.                                  .9120                       .8355            .9333
 B1     2.   241.                    240.                                 1.1360                      1.6188            .9465
 B1     2.   242.                     80.                                 1.0880                       .6005            .8608
 B2     3.   238.                     50.                                  .8909                       .7772            .8092
 B2     3.   239.                     50.                                  .9273                       .9147            .9551
 B2     3.   240.                     60.                                 1.0000                       .8116            .8821
 B2     3.   241.                    240.                                 1.4727                      2.5034           1.9367
 B2     3.   242.                     80.                                  .9455                       .7221            .8755
 C1     4.     1.                    ----                                  ----                        ----             ----
 C1     4.     2.                    ----                                  ----                        ----             ----
 C1     4.     3.                    ----                                  ----                        ----             ----
 C1     4.     4.                    ----                                  ----                        ----             ----
 D1     5.    20.                    ----                                  ----                        ----             ----
 D1     5.     2.                    ----                                  ----                        ----             ----
 D1     5.     1.                    ----                                  ----                        ----             ----
 F1     6.     1.                    ----                                  ----                        ----             ----
 F1     6.     4.                    ----                                  ----                        ----             ----
 F1     6.     5.                    ----                                  ----                        ----             ----
 F1     6.     6.                    ----                                  ----                        ----             ----
 F2     7.     1.                    ----                                  ----                        ----             ----
 F2     7.     5.                    ----                                  ----                        ----             ----
 F2     7.     6.                    ----                                  ----                        ----             ----
 G1     8.  7812.                    ----                                  ----                        ----             ----
 G1     8.  7938.                    ----                                  ----                        ----             ----
 G1     8.  7941.                    ----                                  ----                        ----             ----
 G1     8.  8017.                    ----                                  ----                        ----             ----
 G1     8.  7939.                    ----                                  ----                        ----             ----
 G1     8.  7942.                    ----                                  ----                        ----             ----
 G1     8.  7926.                    ----                                  ----                        ----             ----
 G1     8.  7943.                    ----                                  ----                        ----             ----
 G1     8.  7940.                    ----                                  ----                        ----             ----
 G2     9.  7812.                    ----                                  ----                        ----             ----
 G2     9.  7938.                    ----                                  ----                        ----             ----
 G2     9.  7941.                    ----                                  ----                        ----             ----
 G2     9.  8017.                    ----                                  ----                        ----             ----
 G2     9.  7939.                    ----                                  ----                        ----             ----
 G2     9.  7942.                    ----                                  ----                        ----             ----
 G2     9.  7926.                    ----                                  ----                        ----             ----
 G2     9.  7943.                    ----                                  ----                        ----             ----
 G2     9.  7940.                    ----                                  ----                        ----             ----
 STUDY    FUEL                          N                                        CO                          BAP              SOLUBLE
INFO ID   CODE                         PPM                                      NORM                         NORM               NORM
---- ---  ----  ------  -------  ------ --- ----- ----- ----- ----  ------- -- ---- -------  ------- --- -----  -------
HI   10.    2.                    ----                                          ----                         ----               ----
HI   10.    3.                    ----                                          ----                         ----               ----
HI   10.    6.                    ----                                          ----                         ----               ----
HI   10.    7.                    ----                                          ----                         ----               ----
HI   10.    9.                    ----                                          ----                         ----               ----
HI   10.   11.                    ----                                          ----                         ----               ----
HI   10.   13.                    ----                                          ----                         ----               ----
HI   10.   15.                    ----                                          ----                         ----               ----
HI   10.   16.                    ----                                          ----                         ----               ----
HI   10.   17.                    ----                                          ----                         ----               ----
HI   10.   18.                    ----                                          ----                         ----               ----
HI   10.   19.                    ----                                          ----                         ----               ----
HI   10.   20.                    ----                                          ----                         ----               ----
HI   10.   21.                    ----                                          ----                         ----               ----
HI   10.   22.                    ----                                          ----                         ----               ----
HI   10.   23.                    ----                                          ----                         ----               ----
HI   10.   24.                    ----                                          ----                         ----               ----
HI   10.   25.                    ----                                          ----                         ----               ----
HI   10.   26.                    ----                                          ----                         ----               ----
HI   10.   27.                    ----                                          ----                         ----               ----
HI   10.   28.                    ----                                          ----                         ----               ----
HI   10.   30.                    ----                                          ----                         ----               ----
HI   10.   31.                    ----                                          ----                         ----               ----
HI   10.   32.                    ----                                          ----                         ----               ----
HI   10.   33.                    ----                                          ----                         ----               ----
HI   10.   34.                    ----                                          ----                         ----               ----
HI   10.   35.                    ----                                          ----                         ----               ----
HI   10.   36.                    ----                                          ----                         ----               ----
HI   10.   40.                    ----                                          ----                         ----               ----
HI   10.   43.                    ----                                          ----                         ----               ----
HI   10.   46.                    ----                                          ----                         ----               ----
II   11.    1.                    ----                                          ----                         ----               ----
II   11.    2.                    ----                                          ----                         ----               ----
II   11.    3.                    ----                                          ----                         ----               ----
II   11.    4.                    ----                                          ----                         ----               ----
II   11.    5.                    ----                                          ----                         ----               ----
II   11.    6.                    ----                                          ----                         ----               ----
II   11.    7.                    ----                                          ----                         ----               ----
II   11.    8.                    ----                                          ----                         ----               ----
II   11.    9.                    ----                                          ----                         ----               ----
II   11.   10.                    ----                                          ----                         ----               ----
II   11.   11.                    ----                                          ----                         ----               ----
II   11.   12.                    ----                                          ----                         ----               ----
II   11.   13.                    ----                                          ----                         ----               ----
II   11.   14.                    ----                                          ----                         ----               ----
II   11.   15.                    ----                                          ----                         ----               ----
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  STUDY   FUEL                      N
INFO ID   CODE                     PPM                                  CO                                 BAP          SOLUBLE
---- ---  ----  ------  -------  ------  ---  -----  -----  -----  ----  NORM                               NORM          NORM
                                                                     -------  --  ----  -------  -------  ---  -----  -------
I2    12.    1.                    ----                                ----                               ----          ----
I2    12.    2.                    ----                                ----                               ----          ----
I2    12.    4.                    ----                                ----                               ----          ----
I2    12.    7.                    ----                                ----                               ----          ----
I2    12.   11.                    ----                                ----                               ----          ----
I2    12.   13.                    ----                                ----                               ----          ----
I2    12.    1.                    ----                                ----                               ----          ----
I2    12.    2.                    ----                                ----                               ----          ----
I2    12.    8.                    ----                                ----                               ----          ----
I2    12.   11.                    ----                                ----                               ----          ----
I2    12.   12.                    ----                                ----                               ----          ----
I2    12.   15.                    ----                                ----                               ----          ----
I2    12.    1.                    ----                                ----                               ----          ----
I2    12.    2.                    ----                                ----                               ----          ----
I2    12.    4.                    ----                                ----                               ----          ----
I2    12.   11.                    ----                                ----                               ----          ----
I2    12.   12.                    ----                                ----                               ----          ----
J1    13.  329.                     48.                                ----                               ----          ----
J1    13.  469.                    ----                                ----                               ----          ----
J2    14.  329.                     48.                                ----                               ----          ----
J2    14.  469.                    ----                                ----                               ----          ----
J3    15.  329.                     48.                                ----                               ----          ----
J3    15.  469.                    ----                                ----                               ----          ----
K1    16.  329.                     48.                                ----                               ----          ----
K1    16.  453.                      5.                               .8680                              .6452        1.1507
K1    16.  473.                      1.                               .9584                             1.4722        1.2483
K1    16.  474.                   1600.                              1.0850                             1.3683         .7808
K1    16.  476.                   1000.                              1.0940                             1.9095        1.4537
K1    16.  478.                   2000.                              1.2477                             1.3076        1.3459
K1    16.  482.                    267.                              1.1844                              .4330        2.5941
K1    16.  485.                    142.                              1.0307                             1.0522         .9426
K1    16.  527.                      1.                              1.0488                              .3767          ----
K1    16.  526.                    980.                               .9765                              .8487        1.1121
                                                                     1.0127                              .8227        1.2277
```

STUDY INFO	ID	FUEL CODE	ARO. VOL %	HC NORM	CO NORM	NOX NORM	PART. NORM	BAP NORM	ALDE. NORM
A1	1.	395.	5.8	.7317	.8553	.7996	.7277	1.1281	.3183
A1	1.	401.	2.7	.8943	.8224	.9062	.6426	.8031	5.0205
A1	1.	404.	6.1	.6504	.7730	.8102	.6894	.4780	.3080
A1	1.	405.	6.6	.6504	.7566	.9488	.6894	.6692	15.6057
A1	1.	430.	8.8	.7317	.8553	.8955	.7660	1.8356	0.0000
A1	1.	434.	31.5	.9756	.9704	.9382	.9021	.7075	2.8747
A1	1.	438.	6.8	.7317	.7895	.9062	.6596	.4015	0.0000
A1	1.	448.	4.9	.8943	.7895	.8742	.6043	.9751	8.3984
A1	1.	460.	32.1	1.0569	.9868	.9808	.9319	1.3958	0.0000
A1	1.	461.	5.1	.6504	.7730	.9168	.6766	.8222	9.0657
A1	1.	463.	30.8	1.0569	1.0855	1.1087	1.2213	.8222	0.0000
B1	2.	238.	29.8	.7143	.8837	.9443	.9481	.7753	.8538
B1	2.	2390.	21.6	1.1310	.9922	.9564	.9049	.9145	.8033
B1	2.	240.	13.0	.5357	.8837	.8838	.6772	.6362	.8083
B1	2.	241.	34.6	1.1905	1.1008	1.0654	1.0951	1.2326	1.2074
B1	2.	242.	12.4	.7143	1.0543	1.0291	.8415	.4573	.8538
B2	3.	238.	29.8	.4306	.7692	.9883	.7785	.4960	.7984
B2	3.	239.	21.6	.4785	.8006	1.0888	.7543	.5838	.3505
B2	3.	240.	13.0	.4067	.8634	.9548	.6125	.5180	.5007
B2	3.	241.	34.6	1.6986	1.2716	.9715	1.2976	1.5979	1.4604
B2	3.	242.	12.4	.4785	.8163	1.0553	.6713	.4609	.3728
C1	4.	1.	13.0	.7955	.9302	.7932	.7152	.9746	.6798
C1	4.	2.	27.0	.7197	.9070	.8074	.9536	----	.7279
C1	4.	3.	21.6	1.0985	1.0233	1.1615	.7647	----	1.1249
C1	4.	4.	26.5	1.1364	1.0465	1.0127	.9783	.9949	1.0437
D1	5.	20.	35.1	.7614	.8696	1.0192	.9609	----	1.0866
D1	5.	2.	28.8	1.0660	1.0742	.9952	1.0447	----	1.0342
D1	5.	1.	22.8	1.3198	1.1253	.9712	.9944	----	.8036
F1	6.	1.	23.7	.2834	.6079	1.1247	----	----	----
F1	6.	4.	19.2	.3382	.6336	1.1247	----	----	----
F1	6.	5.	36.9	1.5905	1.2842	.9291	----	----	----
F1	6.	6.	19.2	----	.7449	.9780	----	----	----
F2	7.	1.	23.7	1.4986	1.0513	.9169	----	----	----
F2	7.	5.	36.9	.8174	1.0000	1.0697	----	----	----
F2	7.	6.	19.2	.7902	.9231	.9169	----	----	----
G1	8.	7812.	0.0	----	----	----	----	----	----
G1	8.	7938.	13.0	----	----	----	----	----	----
G1	8.	7941.	13.0	.8000	.7921	1.0571	.9483	----	----
G1	8.	8017.	17.0	----	----	----	----	----	----
G1	8.	7939.	20.0	.8000	.7921	1.1628	1.2069	----	----
G1	8.	7942.	20.0	.8000	.7921	.9514	.9483	----	----
G1	8.	7926.	32.0	.8000	.9901	1.0571	1.0345	----	----
G1	8.	7943.	32.0	1.6000	1.1881	.9514	.9483	----	----
G1	8.	7940.	34.0	.8000	.9901	.9514	.9483	----	----
G2	9.	7812.	0.0	7.1429	1.8634	1.1002	.6329	----	----
G2	9.	7938.	13.0	1.0204	.7764	.8557	.8861	----	----
G2	9.	7941.	13.0	1.0204	.9317	.9780	.9494	----	----
G2	9.	8017.	17.0	2.0408	1.0870	1.1002	.7595	----	----
G2	9.	7939.	20.0	1.0204	.9317	.9780	.8228	----	----
G2	9.	7942.	20.0	1.0204	.9317	.9780	.8861	----	----
G2	9.	7926.	32.0	2.0408	1.3975	1.1002	1.2025	----	----
G2	9.	7943.	32.0	2.0408	.9317	.9780	.8861	----	----
G2	9.	7940.	34.0	2.0408	1.0870	.9780	1.0127	----	----

STUDY		FUEL				ARO.				HC	CO	NOX	PART.		BAP	ALDE.		
INFO	ID	CODE				VOL %				NORM	NORM	NORM	NORM		NORM	NORM		
H1	10.	2.				7.0				3.0606	----	1.3566	.5700		----	----		
H1	10.	3.				7.0				1.4091	----	.9790	.9351		----	----		
H1	10.	6.				3.0				2.9545	----	.9044	.6008		----	----		
H1	10.	7.				3.0				1.2727	----	.8485	.8527		----	----		
H1	10.	9.				6.0				.7576	----	1.0536	.9305		----	----		
H1	10.	11.				17.0				.1061	----	.7879	1.1262		----	----		
H1	10.	13.				13.0				.1061	----	.6620	1.0368		----	----		
H1	10.	15.				14.0				2.6212	----	.8671	.6370		----	----		
H1	10.	16.				28.0				.7121	----	1.1981	.9552		----	----		
H1	10.	17.				46.0				.5758	----	1.2634	1.1724		----	----		
H1	10.	18.				19.0				1.8182	----	.9650	1.1308		----	----		
H1	10.	19.				23.0				.7576	----	.9977	.9559		----	----		
H1	10.	20.				35.0				1.6818	----	1.0769	.8997		----	----		
H1	10.	21.				35.0				1.1212	----	.9977	1.0083		----	----		
H1	10.	22.				34.0				.7727	----	.9604	.7626		----	----		
H1	10.	23.				35.0				.2424	----	1.0443	.9267		----	----		
H1	10.	24.				33.0				.2727	----	.8998	.8866		----	----		
H1	10.	25.				28.0				.1818	----	.9977	.8666		----	----		
H1	10.	26.				17.0				.0758	----	.9277	.9105		----	----		
H1	10.	27.				7.0				.1818	----	.7972	.8766		----	----		
H1	10.	28.				28.0				.2273	----	.8765	1.2186		----	----		
H1	10.	30.				13.0				21.0909	----	1.3986	.6625		----	----		
H1	10.	31.				11.0				.5152	----	1.1981	.9721		----	----		
H1	10.	32.				40.0				.1970	----	.7832	1.1085		----	----		
H1	10.	33.				24.0				.2576	----	.9930	1.0345		----	----		
H1	10.	34.				13.0				.3333	----	1.0163	1.1339		----	----		
H1	10.	35.				13.0				.2576	----	.9837	1.1709		----	----		
H1	10.	36.				14.0				.5303	----	1.0256	1.0253		----	----		
H1	10.	40.				2.0				.0758	----	.4709	.7765		----	----		
H1	10.	43.				19.0				.4394	----	.6434	1.1909		----	----		
H1	10.	46.				.1				.1515	----	.7646	.8851		----	----		
I1	11.	1.				19.9				----	----	----	.5008		----	----		
I1	11.	2.				32.7				----	----	----	.7311		----	----		
I1	11.	3.				20.8				----	----	----	1.0672		----	----		
I1	11.	4.				33.7				----	----	----	1.3899		----	----		
I1	11.	5.				32.1				----	----	----	1.0655		----	----		
I1	11.	6.				47.0				----	----	----	1.5361		----	----		
I1	11.	7.				9.7				----	----	----	.6588		----	----		
I1	11.	8.				57.7				----	----	----	1.6605		----	----		
I1	11.	9.				12.4				----	----	----	.4908		----	----		
I1	11.	10.				57.7				----	----	----	1.5361		----	----		
I1	11.	11.				1.7				----	----	----	.3244		----	----		
I1	11.	12.				.3				----	----	----	.5849		----	----		
I1	11.	13.				0.0				----	----	----	.4387		----	----		
I1	11.	14.				0.0				----	----	----	.5126		----	----		
I1	11.	15.				45.1				----	----	----	.9513		----	----		

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  STUDY     FUEL                           ARO.                           HC      CO     NOX   PART.          BAP   ALDE.
INFO ID     CODE                          VOL %                         NORM    NORM    NORM    NORM         NORM    NORM
---- ---    ----  ------ ------- ----     -----  ----- ----- -----    ----    ----    ----    ----  ----  -----   -----  ----- -----
I2    12.     1.                           19.9                      ----    ----    ----   .9167         ----    ----
I2    12.     2.                           32.7                      ----    ----    ----  1.1780         ----    ----
I2    12.     4.                           33.7                      ----    ----    ----  1.6023         ----    ----
I2    12.     7.                            9.7                      ----    ----    ----   .9167         ----    ----
I2    12.    11.                            1.7                      ----    ----    ----   .5871         ----    ----
I2    12.    13.                            0.0                      ----    ----    ----   .6591         ----    ----
I2    12.     1.                           19.9                      ----    ----    ----   .5417         ----    ----
I2    12.     2.                           32.7                      ----    ----    ----   .6818         ----    ----
I2    12.     8.                           57.7                      ----    ----    ----  1.2462         ----    ----
I2    12.    11.                            1.7                      ----    ----    ----   .3068         ----    ----
I2    12.    12.                             .3                      ----    ----    ----   .4470         ----    ----
I2    12.    15.                           45.1                      ----    ----    ----   .8485         ----    ----
I2    12.     1.                           19.9                      ----    ----    ----  1.0114         ----    ----
I2    12.     2.                           32.7                      ----    ----    ----  1.2235         ----    ----
I2    12.     4.                           33.7                      ----    ----    ----  1.2462         ----    ----
I2    12.    11.                            1.7                      ----    ----    ----   .6591         ----    ----
I2    12.    12.                             .3                      ----    ----    ----   .6591         ----    ----
J1    13.   329.                           21.3                     .9394   .9338   .9716   .9551       1.2821  1.0469
J1    13.   469.                           39.1                    1.0606  1.0698  1.0308  1.0487        .7051   .9510
J2    14.   329.                           21.3                     .8922   .9241  1.0040   .8852        .4946  1.2747
J2    14.   469.                           39.1                    1.1152  1.0781   .9960  1.1202       1.5288   .7127
J3    15.   329.                           21.3                     .9600   .9701   .9922   .9291        .7538  1.3631
J3    15.   469.                           39.1                    1.0400  1.0299  1.0078  1.0748       1.2563   .6196
K1    16.   329.                           21.3                     .7750   .8255   .9192   .8737        .6346  2.1558
K1    16.   453.                           28.5                     .7750   .9114   .9331   .9614       1.4480  1.3859
K1    16.   473.                           22.0                     .9500  1.0318   .9749   .8772       1.3458  2.0018
K1    16.   474.                           34.9                     .9750  1.0404  1.1560  1.1263       1.8782  1.2319
K1    16.   476.                           16.2                    1.7000  1.1866   .9053   .7298       1.2862  1.8479
K1    16.   478.                           39.9                    1.5000  1.1264  1.0585  1.3825        .4259   .3080
K1    16.   482.                           36.4                     .8250   .9802  1.0167   .9860       1.0349   .4620
K1    16.   485.                           25.5                     .8500   .9974  1.0585  1.0491        .3705    ----
K1    16.   527.                           24.0                     .8000   .9286   .8914   .7754        .8348   .3080
K1    16.   526.                           37.2                     .9000   .9630   .9889   .9895        .8092  0.0000
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  STUDY   FUEL                                       OLE.                                          FUEL
INFO ID   CODE                                       VOL %                                         NORM
---- ---  ----  ------ ------- ---- -----            ----- ----- -----  ---- ---- ---- ----  ------- --- ----- ----- -----
 A1     1.  395.                                      1.50                                         .9862
 A1     1.  401.                                      1.90                                         .9956
 A1     1.  404.                                      1.50                                         .9904
 A1     1.  405.                                      1.50                                         .9998
 A1     1.  430.                                      1.80                                        1.0175
 A1     1.  434.                                      2.90                                         .9925
 A1     1.  438.                                      6.60                                        1.0259
 A1     1.  448.                                      1.80                                         .9915
 A1     1.  460.                                      1.00                                         .9967
 A1     1.  461.                                      1.00                                        1.0040
 A1     1.  463.                                      1.20                                        1.0029
 B1     2.  238.                                      1.60                                         .9684
 B1     2. 2390.                                       .80                                         .9821
 B1     2.  240.                                      3.40                                         .9718
 B1     2.  241.                                      1.00                                        1.0711
 B1     2.  242.                                       .80                                        1.0711
 B2     3.  238.                                      1.60                                         .9867
 B2     3.  239.                                       .80                                         .9677
 B2     3.  240.                                      3.40                                         .9867
 B2     3.  241.                                      1.00                                        1.0662
 B2     3.  242.                                       .80                                        1.0178
 C1     4.    1.                                      3.40                                         .9483
 C1     4.    2.                                      1.80                                         .9898
 C1     4.    3.                                       .80                                        1.0527
 C1     4.    4.                                       .90                                        1.0551
 D1     5.   20.                                      0.00                                        1.0657
 D1     5.    2.                                      1.40                                        1.0194
 D1     5.    1.                                      1.10                                        1.0300
 F1     6.    1.                                       .96                                        1.1976
 F1     6.    4.                                       .70                                        1.2434
 F1     6.    5.                                       .72                                        1.2169
 F1     6.    6.                                       .72                                        1.2747
 F2     7.    1.                                       .96                                        1.1473
 F2     7.    5.                                       .72                                        1.2097
 F2     7.    6.                                       .72                                        1.1529
 G1     8. 7812.                                      ----                                         ----
 G1     8. 7938.                                      ----                                         ----
 G1     8. 7941.                                      ----                                         ----
 G1     8. 8017.                                      ----                                         ----
 G1     8. 7939.                                      ----                                         ----
 G1     8. 7942.                                      ----                                         ----
 G1     8. 7926.                                      ----                                         ----
 G1     8. 7943.                                      ----                                         ----
 G1     8. 7940.                                      ----                                         ----
 G2     9. 7812.                                      ----                                         ----
 G2     9. 7938.                                      ----                                         ----
 G2     9. 7941.                                      ----                                         ----
 G2     9. 8017.                                      ----                                         ----
 G2     9. 7939.                                      ----                                         ----
 G2     9. 7942.                                      ----                                         ----
 G2     9. 7926.                                      ----                                         ----
 G2     9. 7943.                                      ----                                         ----
 G2     9. 7940.                                      ----                                         ----
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  STUDY   FUEL                                    OLE.
INFO  ID  CODE                                    VOL %                                FUEL
---- ---  ---- ------ ------- ---- -----          ----- ----- ----- ---- ---- ---- ---- NORM
                                                                                       ------- --- ----- ----- -----
 HI   10.   2.                                    4.00                                 1.0065
 HI   10.   3.                                    4.00                                 1.0137
 HI   10.   6.                                    3.00                                 1.0249
 HI   10.   7.                                    3.00                                  .9848
 HI   10.   9.                                    1.00                                  .9712
 HI   10.  11.                                    4.00                                 1.0009
 HI   10.  13.                                    2.00                                  .9391
 HI   10.  15.                                    1.00                                 1.0169
 HI   10.  16.                                    2.00                                 1.0209
 HI   10.  17.                                    1.00                                 1.0370
 HI   10.  18.                                    2.00                                 1.0314
 HI   10.  19.                                    4.00                                 1.1733
 HI   10.  20.                                    3.00                                 1.0041
 HI   10.  21.                                    2.00                                  .9528
 HI   10.  22.                                    3.00                                  .9993
 HI   10.  23.                                    5.00                                  .9953
 HI   10.  24.                                    3.00                                  .9752
 HI   10.  25.                                    3.00                                 1.0193
 HI   10.  26.                                    3.00                                  .9311
 HI   10.  27.                                    0.00                                  .8774
 HI   10.  28.                                    4.00                                 1.0891
 HI   10.  30.                                    1.00                                 1.1372
 HI   10.  31.                                    1.00                                  .9832
 HI   10.  32.                                    3.00                                 1.0145
 HI   10.  33.                                    3.00                                  .9864
 HI   10.  34.                                    1.00                                  .9937
 HI   10.  35.                                    2.00                                  .9985
 HI   10.  36.                                    1.00                                  .9784
 HI   10.  40.                                    2.00                                 1.0073
 HI   10.  43.                                    ----                                  ----
 HI   10.  46.                                    ----                                  ----
 II   11.   1.                                    ----                                  ----
 II   11.   2.                                    ----                                  ----
 II   11.   3.                                    ----                                  ----
 II   11.   4.                                    ----                                  ----
 II   11.   5.                                    ----                                  ----
 II   11.   6.                                    ----                                  ----
 II   11.   7.                                    ----                                  ----
 II   11.   8.                                    ----                                  ----
 II   11.   9.                                    ----                                  ----
 II   11.  10.                                    ----                                  ----
 II   11.  11.                                    ----                                  ----
 II   11.  12.                                    ----                                  ----
 II   11.  13.                                    ----                                  ----
 II   11.  14.                                    ----                                  ----
 II   11.  15.                                    ----                                  ----
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STUDY INFO	ID	FUEL CODE	OLE. VOL $	FUEL NORM
I2	12.	1.	----	----
I2	12.	2.	----	----
I2	12.	4.	----	----
I2	12.	7.	----	----
I2	12.	11.	----	----
I2	12.	13.	----	----
I2	12.	1.	----	----
I2	12.	2.	----	----
I2	12.	8.	----	----
I2	12.	11.	----	----
I2	12.	12.	----	----
I2	12.	15.	----	----
I2	12.	1.	----	----
I2	12.	2.	----	----
I2	12.	4.	----	----
I2	12.	11.	----	----
I2	12.	12.	----	----
J1	13.	329.	1.70	1.0031
J1	13.	469.	.90	1.0113
J2	14.	329.	1.70	.9953
J2	14.	469.	.90	.9828
J3	15.	329.	1.70	.9982
J3	15.	469.	.90	.9936
K1	16.	329.	1.70	.9839
K1	16.	453.	2.10	1.0241
K1	16.	473.	2.00	1.0226
K1	16.	474.	1.40	.9623
K1	16.	476.	0.00	1.0256
K1	16.	478.	1.20	.9963
K1	16.	482.	0.00	.9438
K1	16.	485.	.50	1.0179
K1	16.	527.	0.00	.9808
K1	16.	526.	1.20	.9546

STUDY INFO	ID	FUEL CODE	10%PT DEG C	HC NORM	NOX NORM	PART. NORM
A1	1.	395.	211.	1.0588	.8782	.9096
A1	1.	401.	206.	1.2941	.9953	.8032
A1	1.	404.	211.	.9412	.8899	.8617
A1	1.	405.	210.	.9412	1.0422	.8617
A1	1.	430.	210.	1.0588	.9836	.9574
A1	1.	434.	206.	1.4118	1.0304	1.1277
A1	1.	438.	210.	1.0588	.9953	.8245
A1	1.	448.	189.	1.2941	.9602	.7553
A1	1.	460.	209.	1.5294	1.0773	1.1649
A1	1.	461.	216.	.9412	1.0070	.8457
A1	1.	463.	206.	1.5294	1.2178	1.5266
B1	2.	238.	213.	.7018	.9286	.9536
B1	2.	2390.	216.	1.1111	.9405	.9101
B1	2.	240.	181.	.5263	.8690	.6812
B1	2.	241.	216.	1.1696	1.0476	1.1014
B1	2.	242.	213.	.7018	1.0119	.8464
B2	3.	238.	213.	.5042	.9532	.8396
B2	3.	239.	216.	.5602	1.0501	.8134
B2	3.	240.	181.	.4762	.9208	.6604
B2	3.	241.	216.	1.9888	.9370	1.3993
B2	3.	242.	215.	.5602	1.0178	.7239
C1	4.	1.	181.	.7292	.7306	.7726
C1	4.	2.	204.	.6597	.7436	1.0301
C1	4.	3.	216.	1.0069	1.0698	.8261
C1	4.	4.	214.	1.0417	.9328	1.0569
D1	5.	20.	223.	.8427	1.0119	.9663
D1	5.	2.	217.	1.1798	.9881	1.0506
D1	5.	1.	205.	1.4607	.9643	1.0000
F1	6.	1.	197.	1.2917	.9350	----
F1	6.	4.	151.	1.5417	.9350	----
F1	6.	5.	139.	7.2500	.7724	----
F1	6.	6.	136.	----	.8130	----
F2	7.	1.	197.	.8488	1.0256	----
F2	7.	5.	139.	.4630	1.1966	----
F2	7.	6.	136.	.4475	1.0256	----
G1	8.	7812.	209.	----	----	----
G1	8.	7938.	206.	----	----	----
G1	8.	7941.	213.	1.2500	.9488	.9322
G1	8.	8017.	188.	----	----	----
G1	8.	7939.	203.	1.2500	1.0436	1.1864
G1	8.	7942.	201.	1.2500	.8539	.9322
G1	8.	7926.	214.	1.2500	.9488	1.0169
G1	8.	7943.	199.	2.5000	.8539	.9322
G1	8.	7940.	199.	1.2500	.8539	.9322
G2	9.	7812.	209.	2.6022	1.1029	.6250
G2	9.	7938.	206.	.3717	.8578	.8750
G2	9.	7941.	213.	.3717	.9804	.9375
G2	9.	8017.	188.	.7435	1.1029	.7500
G2	9.	7939.	203.	.3717	.9804	.8125
G2	9.	7942.	201.	.3717	.9804	.8750
G2	9.	7926.	214.	.7435	1.1029	1.1875
G2	9.	7943.	199.	.7435	.9804	.8750
G2	9.	7940.	199.	.7435	.9804	1.0000

STUDY INFO	ID	FUEL CODE						10%PT DEG C		HC NORM		NOX NORM	PART. NORM					
H1	10.	2.						54.		9.6651		1.5008	.5616					
H1	10.	3.						54.		4.4498		1.0830	.9214					
H1	10.	6.						63.		9.3301		1.0005	.5920					
H1	10.	7.						63.		4.0191		.9386	.8402					
H1	10.	9.						79.		2.3923		1.1655	.9168					
H1	10.	11.						201.		.3349		.8716	1.1096					
H1	10.	13.						165.		.3349		.7323	1.0216					
H1	10.	15.						125.		8.2775		.9593	.6277					
H1	10.	16.						133.		2.2488		1.3254	.9411					
H1	10.	17.						267.		1.8182		1.3976	1.1551					
H1	10.	18.						143.		5.7416		1.0676	1.1141					
H1	10.	19.						219.		2.3923		1.1037	.9419					
H1	10.	20.						198.		5.3110		1.1913	.8865					
H1	10.	21.						222.		3.5407		1.1037	.9935					
H1	10.	22.						203.		2.4402		1.0624	.7514					
H1	10.	23.						221.		.7656		1.1552	.9130					
H1	10.	24.						213.		.8612		.9954	.8736					
H1	10.	25.						214.		.5742		1.1037	.8538					
H1	10.	26.						190.		.2392		1.0263	.8971					
H1	10.	27.						101.		.5742		.8819	.8637					
H1	10.	28.						222.		.7177		.9696	1.2007					
H1	10.	30.						85.		66.6029		1.5472	.6527					
H1	10.	31.						117.		1.6268		1.3254	.9578					
H1	10.	32.						233.		.6220		.8664	1.0921					
H1	10.	33.						204.		.8134		1.0985	1.0193					
H1	10.	34.						85.		1.0526		1.1243	1.1172					
H1	10.	35.						165.		.8134		1.0882	1.1536					
H1	10.	36.						79.		1.6746		1.1346	1.0102					
H1	10.	40.						215.		.2392		.5209	.7650					
H1	10.	43.						221.		1.3876		.7117	1.1733					
H1	10.	46.						190.		.4785		.8458	.8720					
I1	11.	1.						197.		----		----	.5709					
I1	11.	2.						209.		----		----	.8333					
I1	11.	3.						262.		----		----	1.2165					
I1	11.	4.						271.		----		----	1.5843					
I1	11.	5.						254.		----		----	1.2146					
I1	11.	6.						261.		----		----	1.7510					
I1	11.	7.						258.		----		----	.7510					
I1	11.	8.						254.		----		----	1.8927					
I1	11.	9.						112.		----		----	.5594					
I1	11.	10.						177.		----		----	1.7510					
I1	11.	11.						211.		----		----	.3697					
I1	11.	12.						309.		----		----	.6667					
I1	11.	13.						221.		----		----	.5000					
I1	11.	14.						231.		----		----	.5843					
I1	11.	15.						191.		----		----	1.0843					

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  STUDY    FUEL                                          10%PT          HC              NOX    PART.
INFO  ID   CODE                                          DEG C         NORM             NORM   NORM
---- ---   ----  ------ ------- ---- ----- -----         -----  ----   ----    ----     ----   ----  ------- ----- ----- ----- -----
I2   12.     1.                                           197.          ----             ----  1.0708
I2   12.     2.                                           209.          ----             ----  1.3761
I2   12.     4.                                           271.          ----             ----  1.8717
I2   12.     7.                                           258.          ----             ----  1.0708
I2   12.    11.                                           211.          ----             ----   .6858
I2   12.    13.                                           221.          ----             ----   .7699
I2   12.     1.                                           197.          ----             ----   .6327
I2   12.     2.                                           209.          ----             ----   .7965
I2   12.     8.                                           254.          ----             ----  1.4558
I2   12.    11.                                           211.          ----             ----   .3584
I2   12.    12.                                           309.          ----             ----   .5221
I2   12.    15.                                           191.          ----             ----   .9912
I2   12.     1.                                           197.          ----             ----  1.1814
I2   12.     2.                                           209.          ----             ----  1.4292
I2   12.     4.                                           271.          ----             ----  1.4558
I2   12.    11.                                           211.          ----             ----   .7699
I2   12.    12.                                           309.          ----             ----   .7699
J1   13.   329.                                           219.        1.0032            .9988  1.0039
J1   13.   469.                                           307.        1.1327           1.0597  1.1024
J2   14.   329.                                           219.        1.0000            .9992   .9939
J2   14.   469.                                           307.        1.2500            .9913  1.2577
J3   15.   329.                                           219.        1.0084           1.0016  1.0000
J3   15.   469.                                           307.        1.0924           1.0172  1.1568
K1   16.   329.                                           219.         .8708            .9154   .8527
K1   16.   453.                                           236.         .8708            .9293   .9384
K1   16.   473.                                           189.        1.0674            .9709   .8562
K1   16.   474.                                           234.        1.0955           1.1512  1.0993
K1   16.   476.                                            53.        1.9101            .9015   .7123
K1   16.   478.                                           209.        1.6854           1.0541  1.3493
K1   16.   482.                                           207.         .9270           1.0125   .9623
K1   16.   485.                                           157.         .9551           1.0541  1.0240
K1   16.   527.                                           200.         .8989            .8877   .7568
K1   16.   526.                                           212.        1.0112            .9847   .9658
```

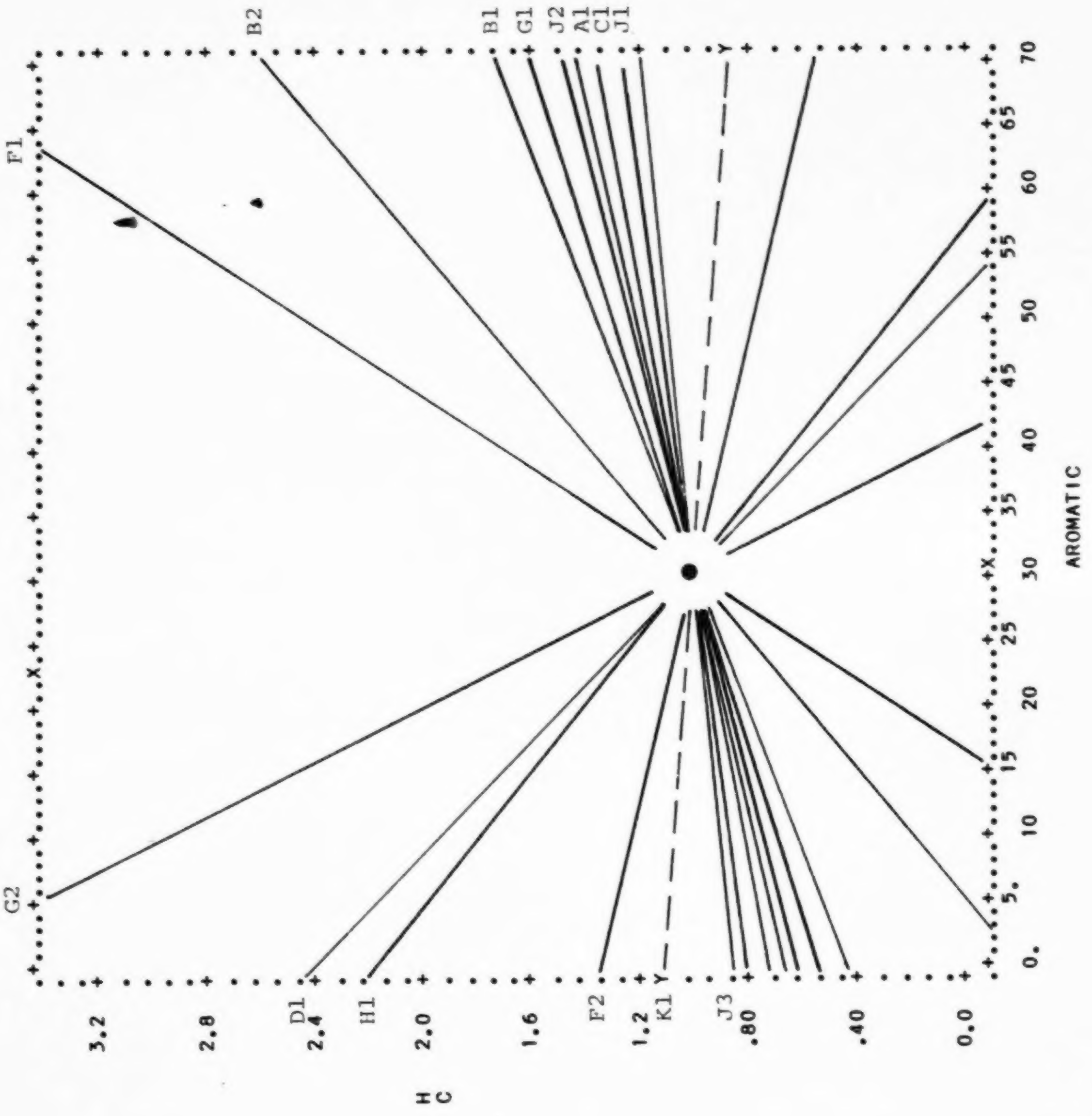
```
  STUDY   FUEL                                                  90%PT     HC                    PART.
INFO ID   CODE                                                  DEG C    NORM                   NORM
---- ---  ----  ------ ------- ---- ----- ----- -----           -----    ----   ----   ----      ----   ----  -----  -----  -----  -----
A1     1.  395.                                                  224.   .8911                   .8182
A1     1.  401.                                                  239. 1.0891                    .7225
A1     1.  404.                                                  224.   .7921                   .7751
A1     1.  405.                                                  224.   .7921                   .7751
A1     1.  430.                                                  228.   .8911                   .8612
A1     1.  434.                                                  234. 1.1881                   1.0144
A1     1.  438.                                                  224.   .8911                   .7416
A1     1.  448.                                                  223. 1.0891                    .6794
A1     1.  460.                                                  224. 1.2871                   1.0478
A1     1.  461.                                                  251.   .7921                   .7608
A1     1.  463.                                                  234. 1.2871                   1.3732
B1     2.  238.                                                  313.   .8054                  1.0313
B1     2. 2390.                                                  303. 1.2752                    .9843
B1     2.  240.                                                  238.   .6040                   .7367
B1     2.  241.                                                  301. 1.3423                   1.1912
B1     2.  242.                                                  310.   .8054                   .9154
B2     3.  238.                                                  313.   .6000                   .9184
B2     3.  239.                                                  303.   .6667                   .8898
B2     3.  240.                                                  238.   .5667                   .7224
B2     3.  241.                                                  301. 2.3667                   1.5306
B2     3.  242.                                                  310.   .6667                   .7918
C1     4.    1.                                                  238.   .7778                   .7938
C1     4.    2.                                                  280.   .7037                  1.0584
C1     4.    3.                                                  303. 1.0741                    .8488
C1     4.    4.                                                  306. 1.1111                   1.0859
D1     5.   20.                                                  316.   .6024                   .9503
D1     5.    2.                                                  309.   .8434                  1.0331
D1     5.    1.                                                  297. 1.0442                    .9834
F1     6.    1.                                                  290.   .3949                   ----
F1     6.    4.                                                  303.   .4713                   ----
F1     6.    5.                                                  308. 2.2166                    ----
F1     6.    6.                                                  279.   ----                    ----
F2     7.    1.                                                  290. 1.4785                    ----
F2     7.    5.                                                  308.   .8065                   ----
F2     7.    6.                                                  279.   .7796                   ----
G1     8. 7812.                                                  247.   ----                    ----
G1     8. 7938.                                                  226.   ----                    ----
G1     8. 7941.                                                  309. 1.1236                    .9565
G1     8. 8017.                                                  244.   ----                    ----
G1     8. 7939.                                                  249. 1.1236                   1.2174
G1     8. 7942.                                                  227. 1.1236                    .9565
G1     8. 7926.                                                  306. 1.1236                   1.0435
G1     8. 7943.                                                  312. 2.2472                    .9565
G1     8. 7940.                                                  251. 1.1236                    .9565
G2     9. 7812.                                                  247. 3.5354                    .6536
G2     9. 7938.                                                  226.   .5051                   .9150
G2     9. 7941.                                                  309.   .5051                   .9804
G2     9. 8017.                                                  244. 1.0101                    .7843
G2     9. 7939.                                                  249.   .5051                   .8497
G2     9. 7942.                                                  227.   .5051                   .9150
G2     9. 7926.                                                  306. 1.0101                   1.2418
G2     9. 7943.                                                  312. 1.0101                    .9150
G2     9. 7940.                                                  251. 1.0101                   1.0458
```

```
   STUDY    FUEL                                                    90%PT    HC                PART.
 INFO  ID   CODE                                                    DEG C    NORM              NORM
 ---- ---   ----  ------ ------- ---- ----- ----- -----             -----    ----  ----  ----  ----  ----  -----  -----  -----  -----
 HI   10.    2.                                                      130.  3.1661               .5746
 HI   10.    3.                                                      130.  1.4577               .9427
 HI   10.    6.                                                       92.  3.0564               .6057
 HI   10.    7.                                                       92.  1.3166               .8596
 HI   10.    9.                                                      122.   .7837               .9380
 HI   10.   11.                                                      255.   .1097              1.1353
 HI   10.   13.                                                      186.   .1097              1.0452
 HI   10.   15.                                                      235.  2.7116               .6422
 HI   10.   16.                                                      308.   .7367               .9629
 HI   10.   17.                                                      320.   .5956              1.1819
 HI   10.   18.                                                      309.  1.8809              1.1399
 HI   10.   19.                                                      314.   .7837               .9637
 HI   10.   20.                                                      296.  1.7398               .9070
 HI   10.   21.                                                      314.  1.1599              1.0165
 HI   10.   22.                                                      297.   .7994               .7688
 HI   10.   23.                                                      314.   .2508               .9342
 HI   10.   24.                                                      307.   .2821               .8938
 HI   10.   25.                                                      311.   .1881               .8736
 HI   10.   26.                                                      247.   .0784               .9178
 HI   10.   27.                                                      233.   .1881               .8837
 HI   10.   28.                                                      303.   .2351              1.2285
 HI   10.   30.                                                      208.21.8182               .6678
 HI   10.   31.                                                      246.   .5329               .9800
 HI   10.   32.                                                      311.   .2038              1.1174
 HI   10.   33.                                                      309.   .2665              1.0429
 HI   10.   34.                                                      208.   .3448              1.1430
 HI   10.   35.                                                      186.   .2665              1.1803
 HI   10.   36.                                                      145.   .5486              1.0335
 HI   10.   40.                                                      233.   .0784               .7827
 HI   10.   43.                                                      358.   .4545              1.2005
 HI   10.   46.                                                      320.   .1567               .8922
 II   11.    1.                                                      256.   ----                .6835
 II   11.    2.                                                      317.   ----                .9977
 II   11.    3.                                                      364.   ----               1.4564
 II   11.    4.                                                      363.   ----               1.8968
 II   11.    5.                                                      349.   ----               1.4541
 II   11.    6.                                                      364.   ----               2.0963
 II   11.    7.                                                      354.   ----                .8991
 II   11.    8.                                                      367.   ----               2.2661
 II   11.    9.                                                      224.   ----                .6697
 II   11.   10.                                                      346.   ----               2.0963
 II   11.   11.                                                      246.   ----                .4427
 II   11.   12.                                                      365.   ----                .7982
 II   11.   13.                                                      342.   ----                .5986
 II   11.   14.                                                      357.   ----                .6995
 II   11.   15.                                                      328.   ----               1.2982
```

```
  STUDY   FUEL
INFO ID   CODE                                                     90%PT    HC            PART.
---- ---  ----  ------  -------  ----  -----  -----  -----         DEG C   NORM            NORM
                                                                   -----   ----  ----  ----  ----  ----  -----  -----  -----  -----
I2    12.    1.                                                     256.   ----           1.1000
I2    12.    2.                                                     317.   ----           1.4136
I2    12.    4.                                                     363.   ----           1.9227
I2    12.    7.                                                     354.   ----           1.1000
I2    12.   11.                                                     246.   ----            .7045
I2    12.   13.                                                     342.   ----            .7909
I2    12.    1.                                                     256.   ----            .6500
I2    12.    2.                                                     317.   ----            .8182
I2    12.    8.                                                     367.   ----           1.4955
I2    12.   11.                                                     246.   ----            .3682
I2    12.   12.                                                     365.   ----            .5364
I2    12.   15.                                                     328.   ----           1.0182
I2    12.    1.                                                     256.   ----           1.2136
I2    12.    2.                                                     317.   ----           1.4682
I2    12.    4.                                                     363.   ----           1.4955
I2    12.   11.                                                     246.   ----            .7909
I2    12.   12.                                                     365.   ----            .7909
J1    13.  329.                                                     219.   .8986           .9239
J1    13.  469.                                                     315.  1.0145          1.0145
J2    14.  329.                                                     219.   .8219           .8141
J2    14.  469.                                                     315.  1.0274          1.0302
J3    15.  329.                                                     219.   .9449           .8773
J3    15.  469.                                                     315.  1.0236          1.0149
K1    16.  329.                                                     302.   .7654           .8957
K1    16.  453.                                                     295.   .7654           .9856
K1    16.  473.                                                     228.   .9383           .8993
K1    16.  474.                                                     330.   .9630          1.1547
K1    16.  476.                                                     303.  1.6790           .7482
K1    16.  478.                                                     303.  1.4815          1.4173
K1    16.  482.                                                     316.   .8148          1.0108
K1    16.  485.                                                     302.   .8395          1.0755
K1    16.  527.                                                     392.   .7901           .7950
K1    16.  526.                                                     316.   .8889          1.0144
```

APPENDIX E

SCATTERGRAMS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1.6
1.2
.80
.40
0.0
AROMATIC
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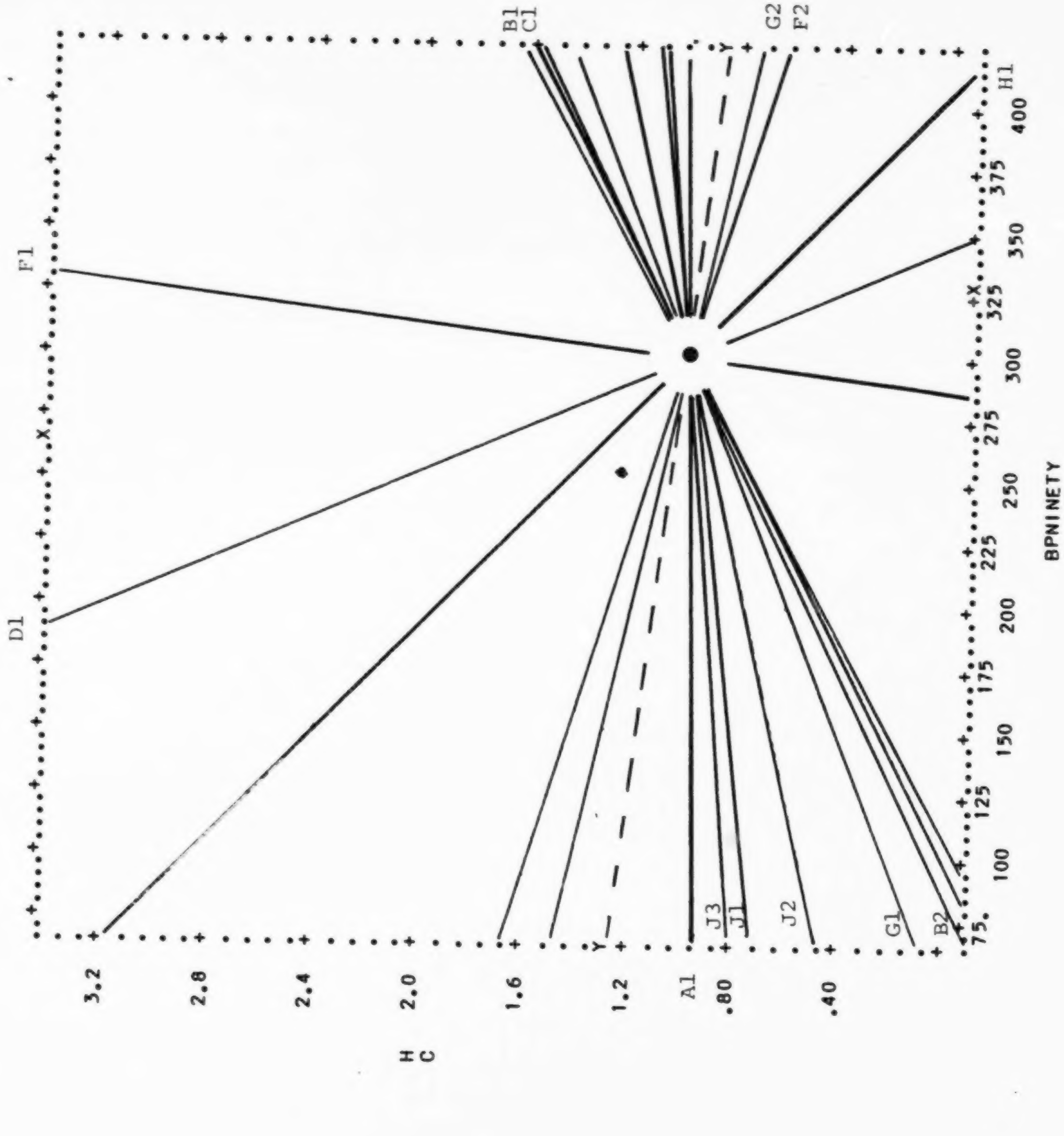
5.
10
15
20
25
30
35
40
45
50
55
60
65
70
G2
F1
B2
B1
G1
J2
A1
C1
J1
Y
D1
H1
F2
K1
Y
J3
X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C
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2.0
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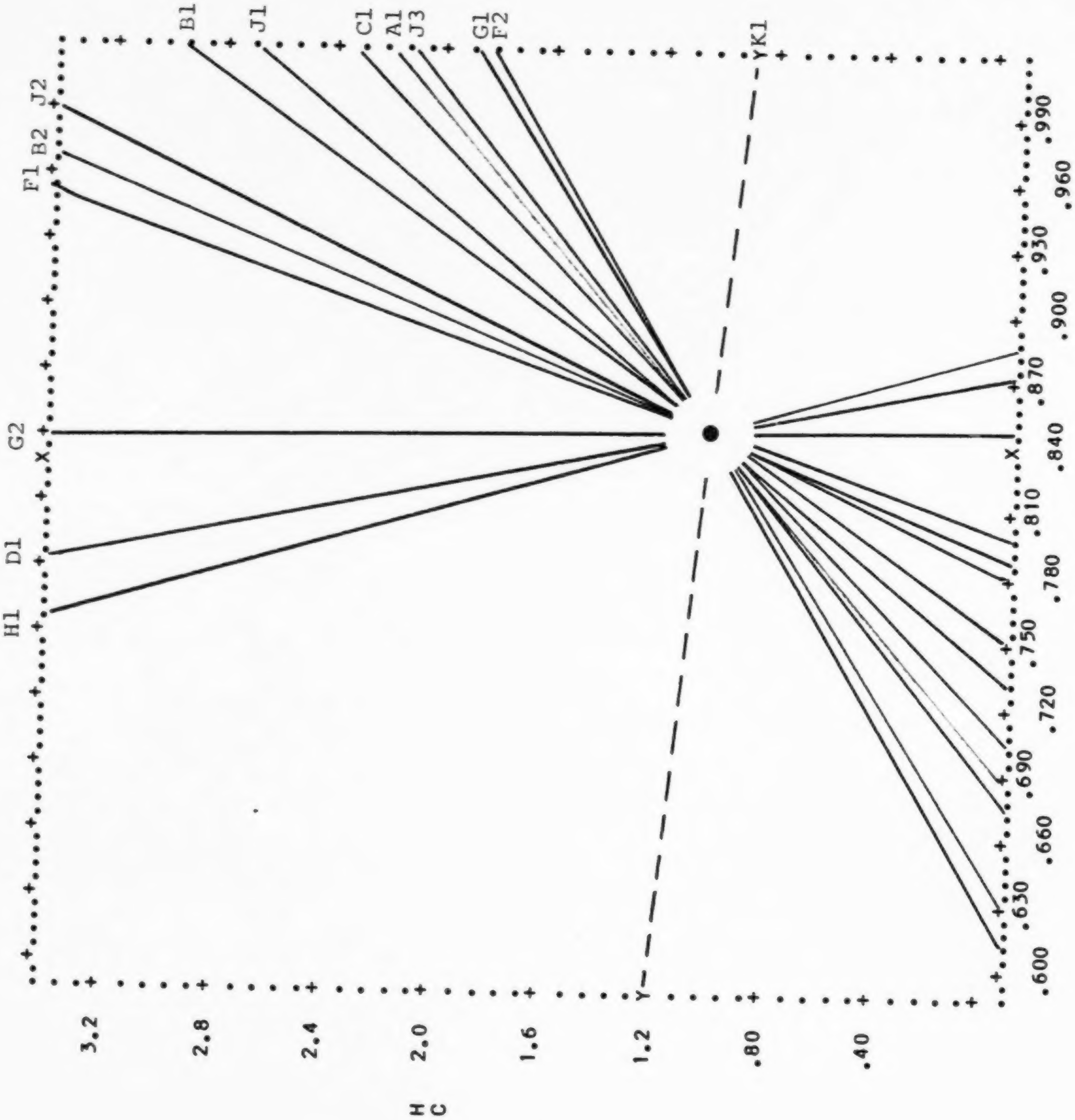
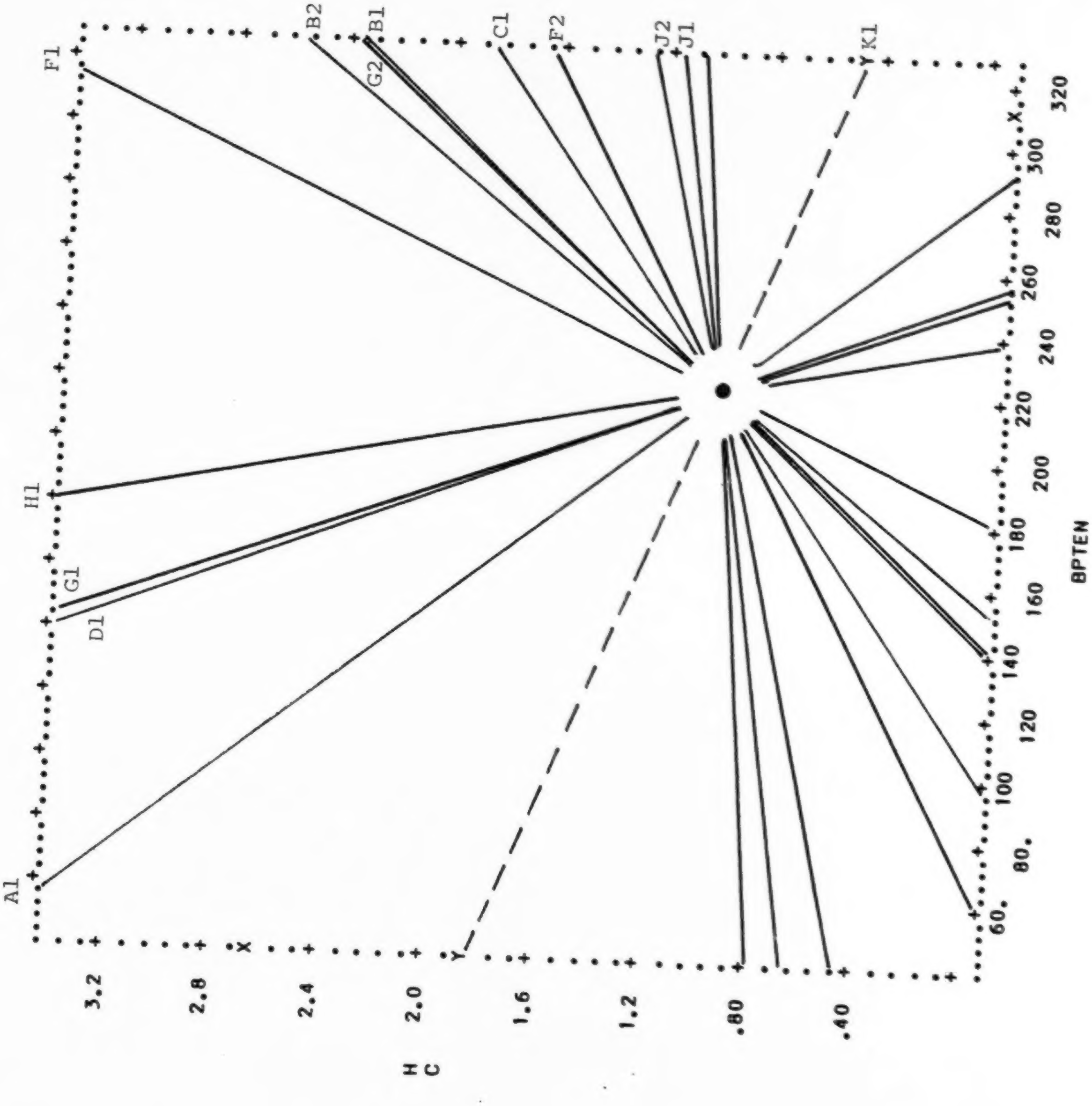
1.2
A1
.80
.40
BPNINETY
75
100
125
150
175
200
225
250
275
300
325
350
375
400
D1
F1
X
B1
C1
Y
G2
F2
H1
J3
J1
J2
G1
B2



H
C
3.2
2.8
2.4
2.0
1.6
1.2
.80
.40
.600
.630
.660
.690
.720
.750
.780
.810
.840
.870
.900
.930
.960
.990
DENSITY
H1
D1
G2
F1
B2
J2
B1
J1
C1
A1
J3
G1
F2
YK1
X
Y


A1
F1
B2
B1
G2
C1
F2
J2
J1
K1
H1
G1
D1
X
Y
3.2
2.8
2.4
2.0
1.6
1.2
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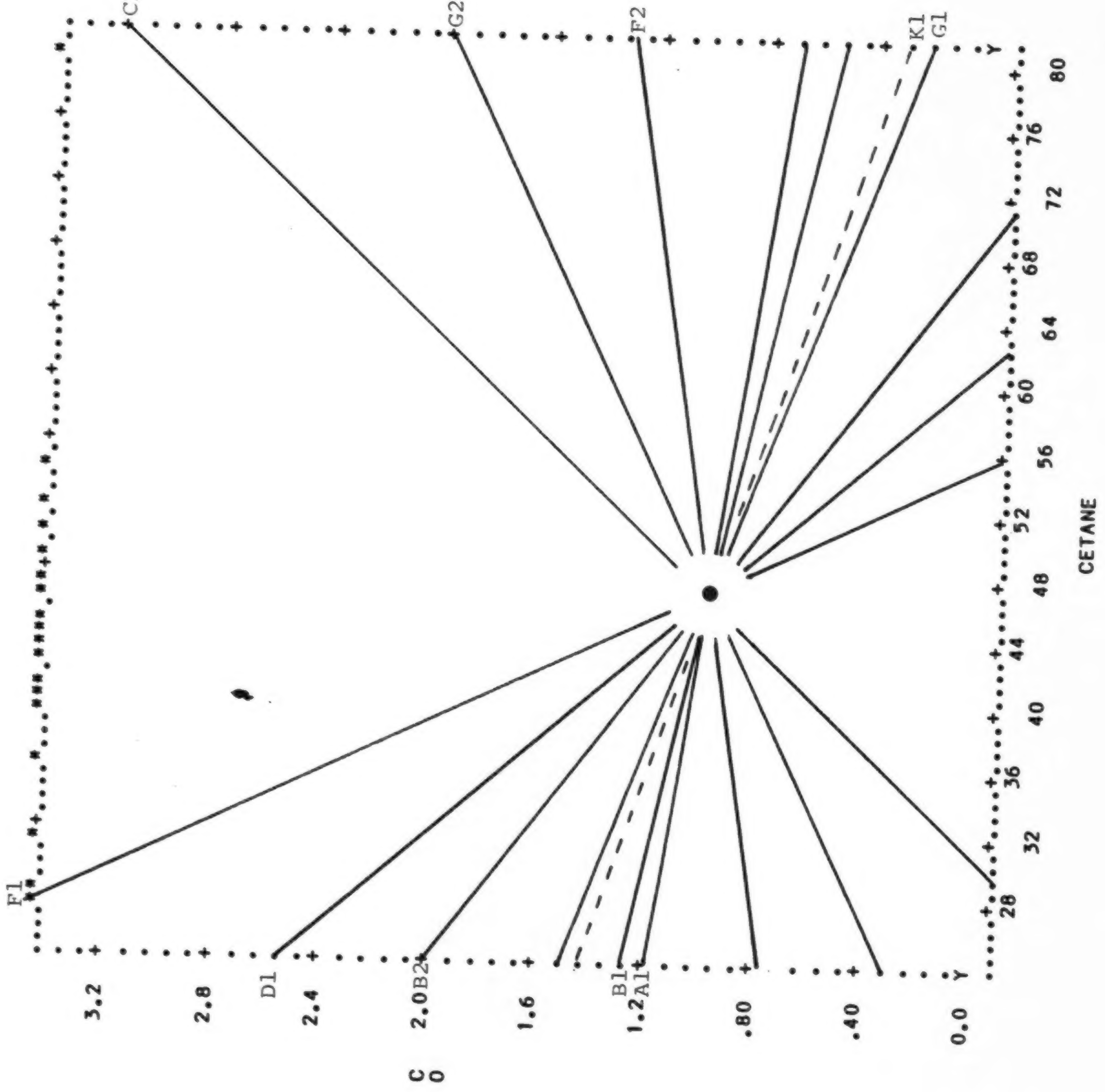
.40
HC
60
80
100
120
140
160
180
200
220
240
260
280
300
320
BPTEN


C
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.80
.40
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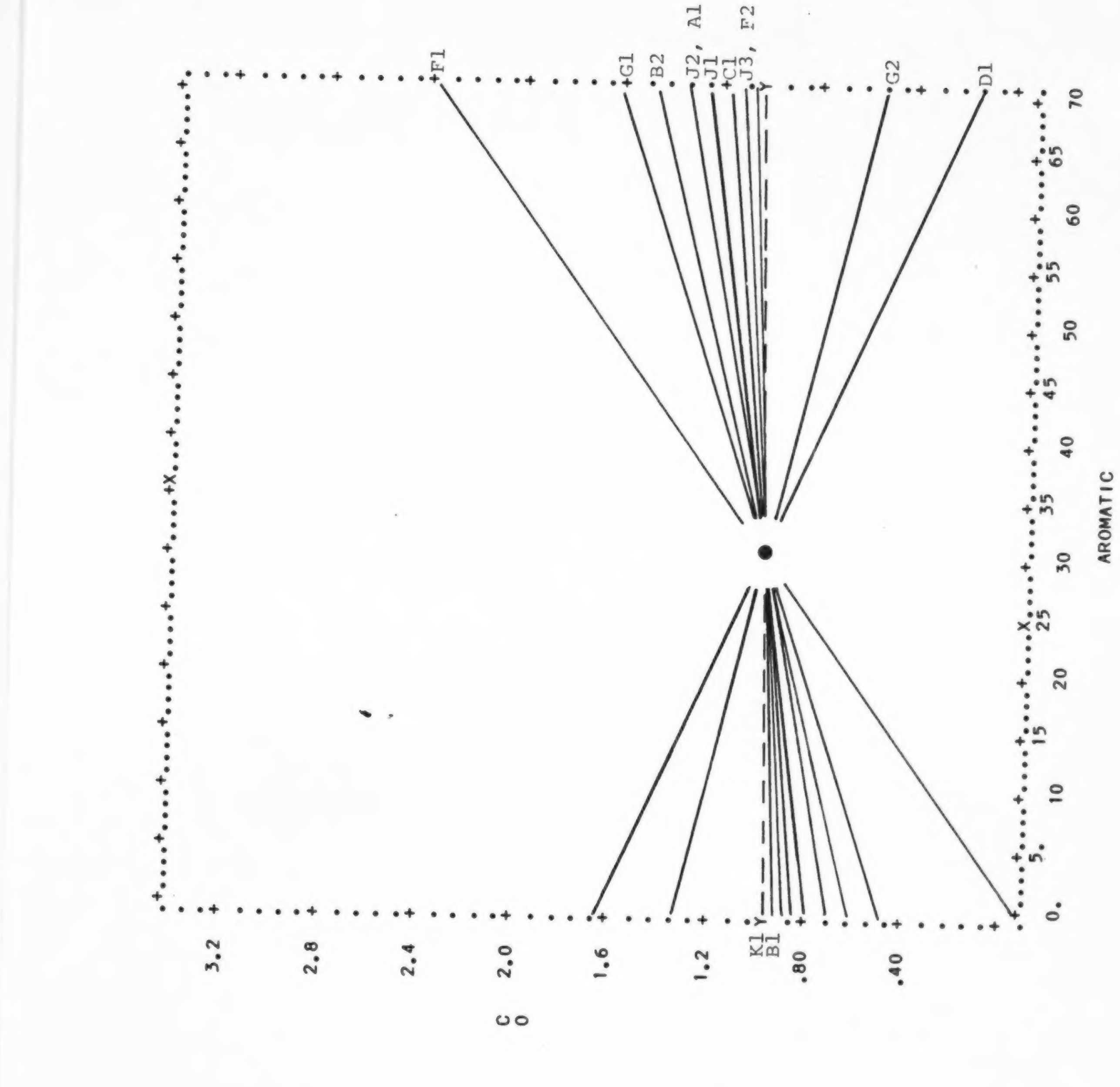
Y
CETANE
28
32
36
40
44
48
52
56
60
64
68
72
76
80
Y
F1
C1
G2
F2
K1
G1
D1
B2
B1
A1



C
O
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2.8
2.4
2.0
1.6
1.2
K1 Y
B1
.80
.40
0.
5.
10
15
20
25
30
35
40
45
50
55
60
65
70
AROMATIC
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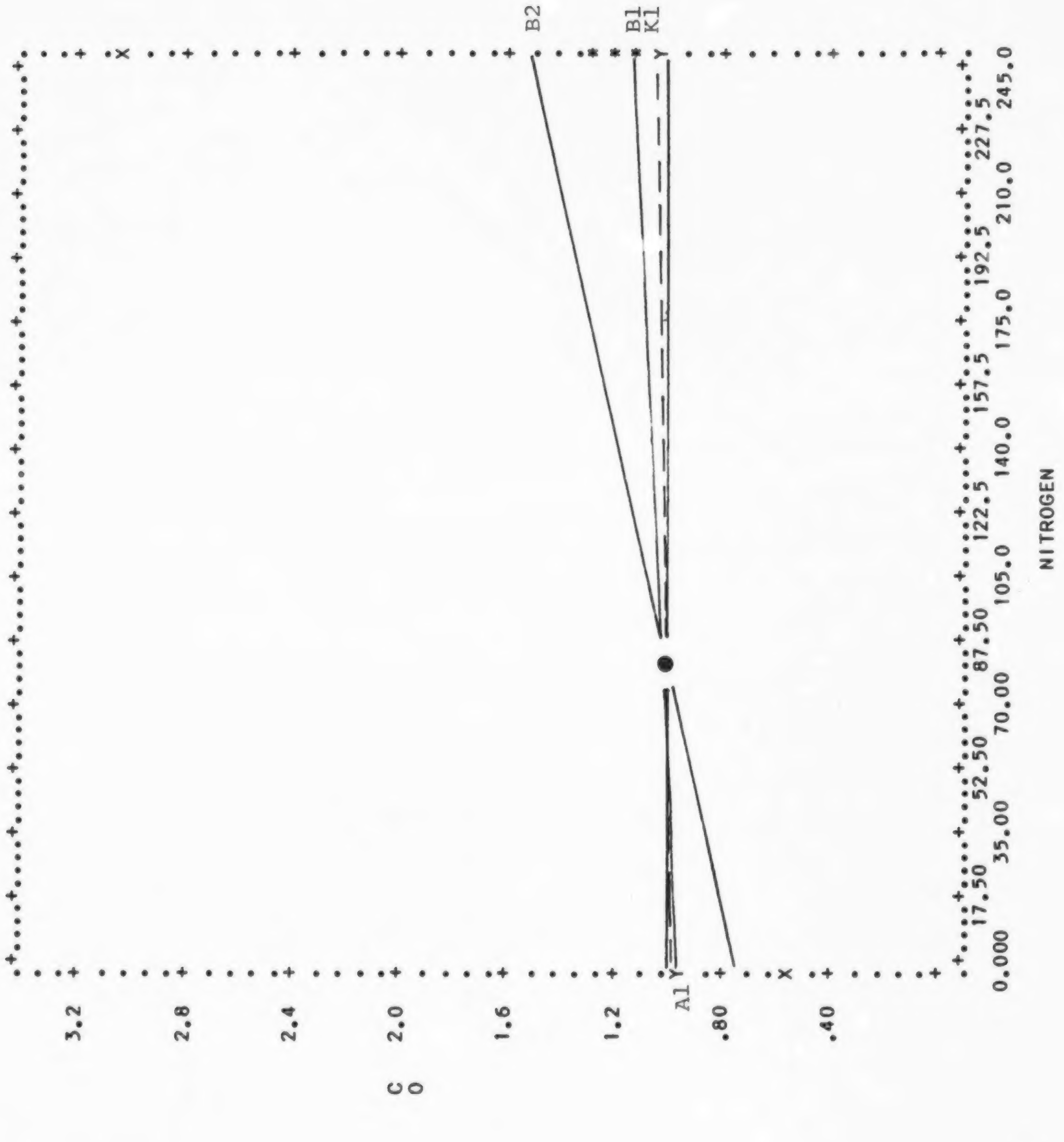
G1
B2
J2, A1
J1
C1
J3, F2
Y
G2
D1
X
X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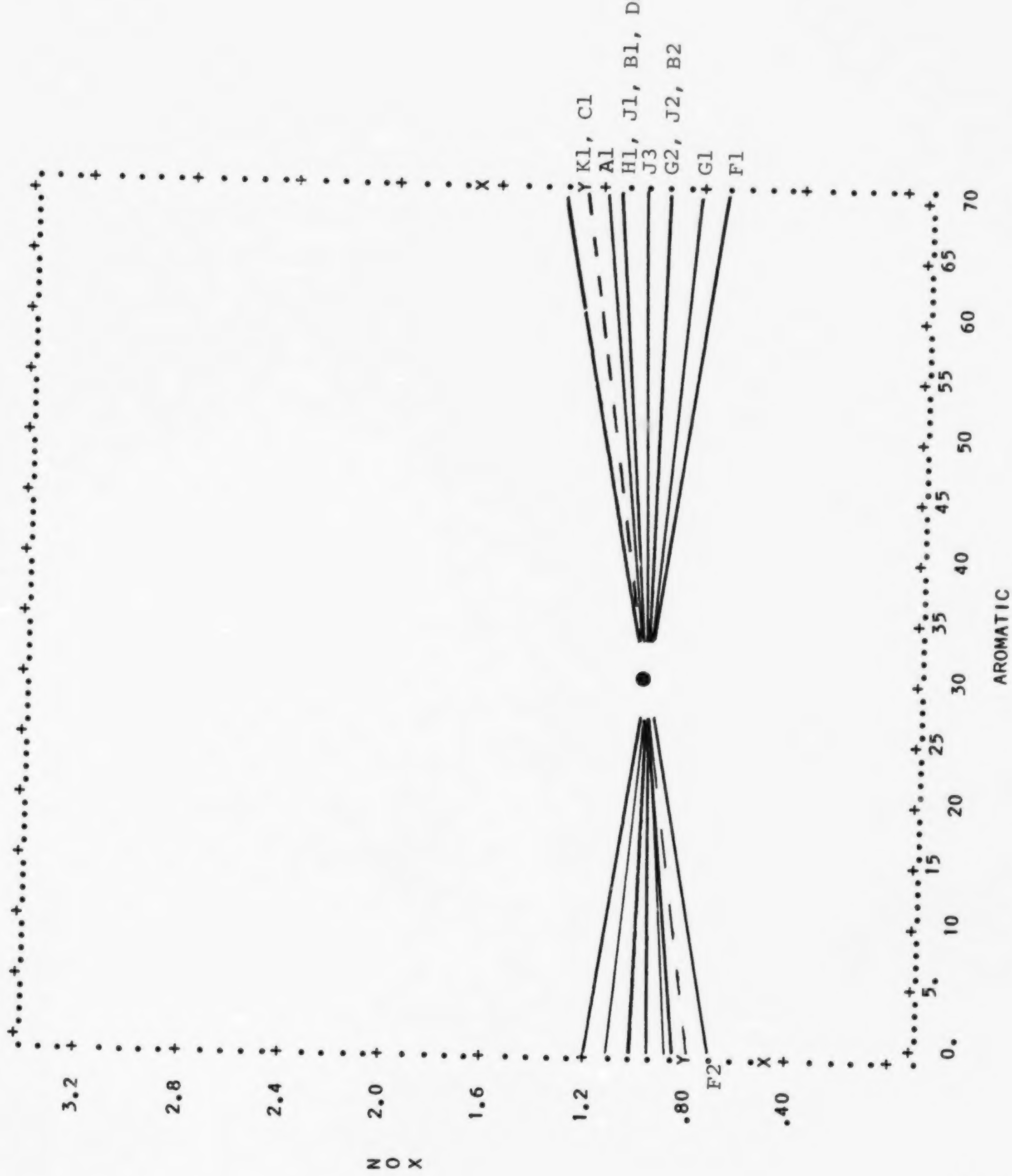
52.50
70.00
87.50
105.0
122.5
140.0
157.5
175.0
192.5
210.0
227.5
245.0
NITROGEN
B2
B1
K1
Y
X
A1
Y
X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.40
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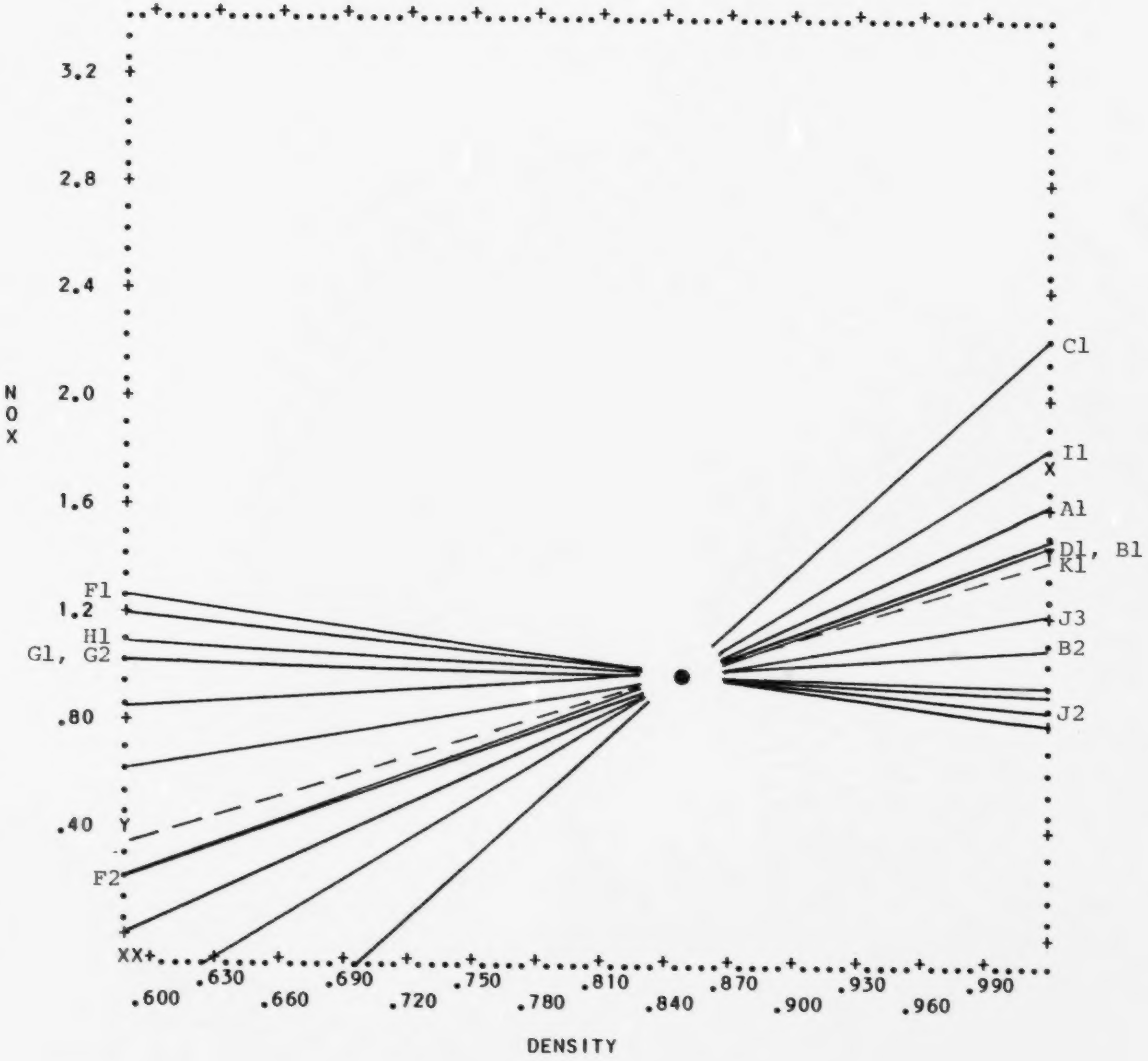
5.
10
15
20
25
30
35
40
45
50
55
60
65
70
AROMATIC
Y K1, C1
A1
H1, J1, B1, D1
J3
G2, J2, B2
G1
F1
Y
F2
X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G1, G2
Y
F2
XX
C1
I1
X
A1
D1, B1
K1
J3
B2
J2
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.900
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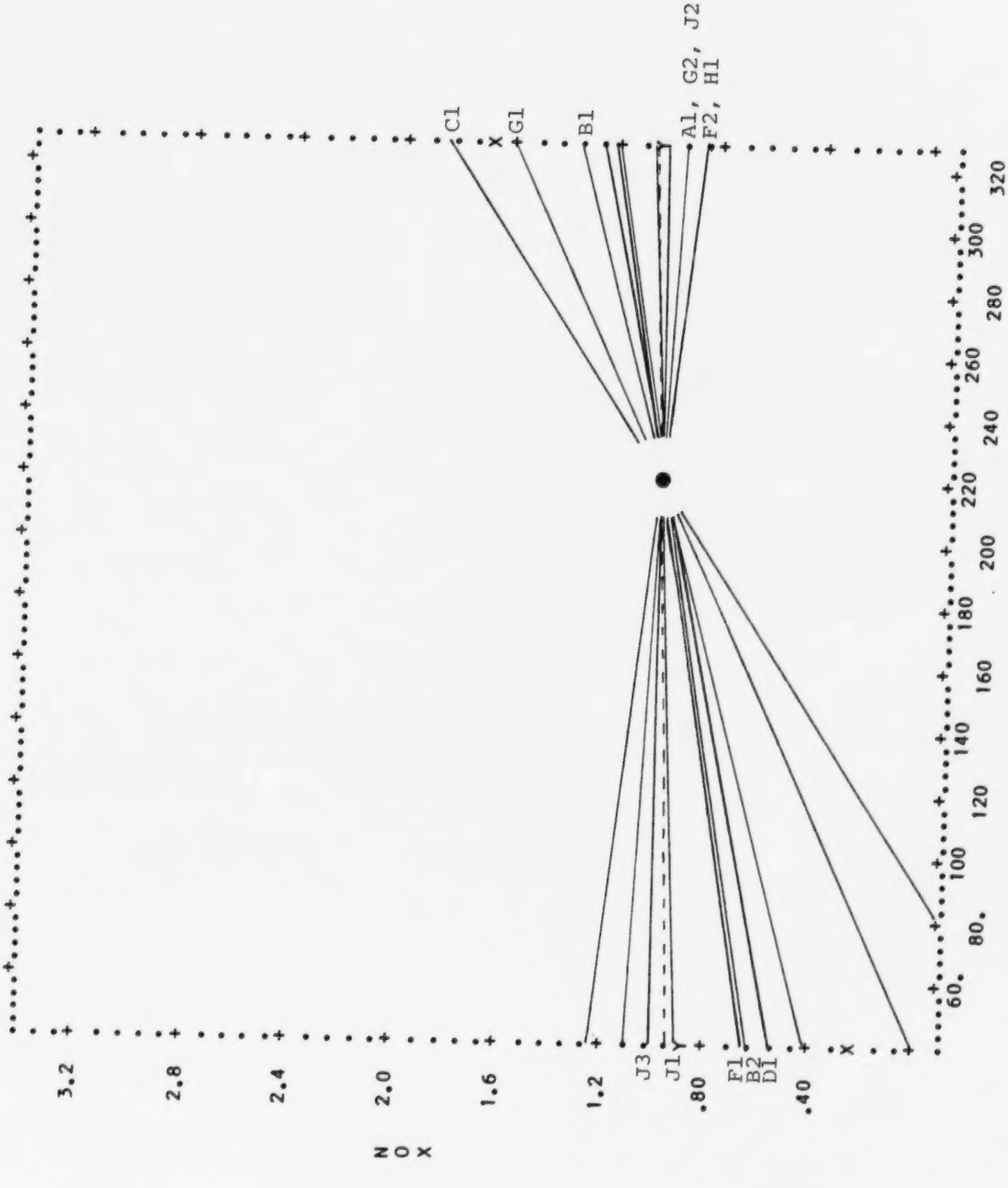
.960
.990
DENSITY



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2.4
2.0
1.6
1.2
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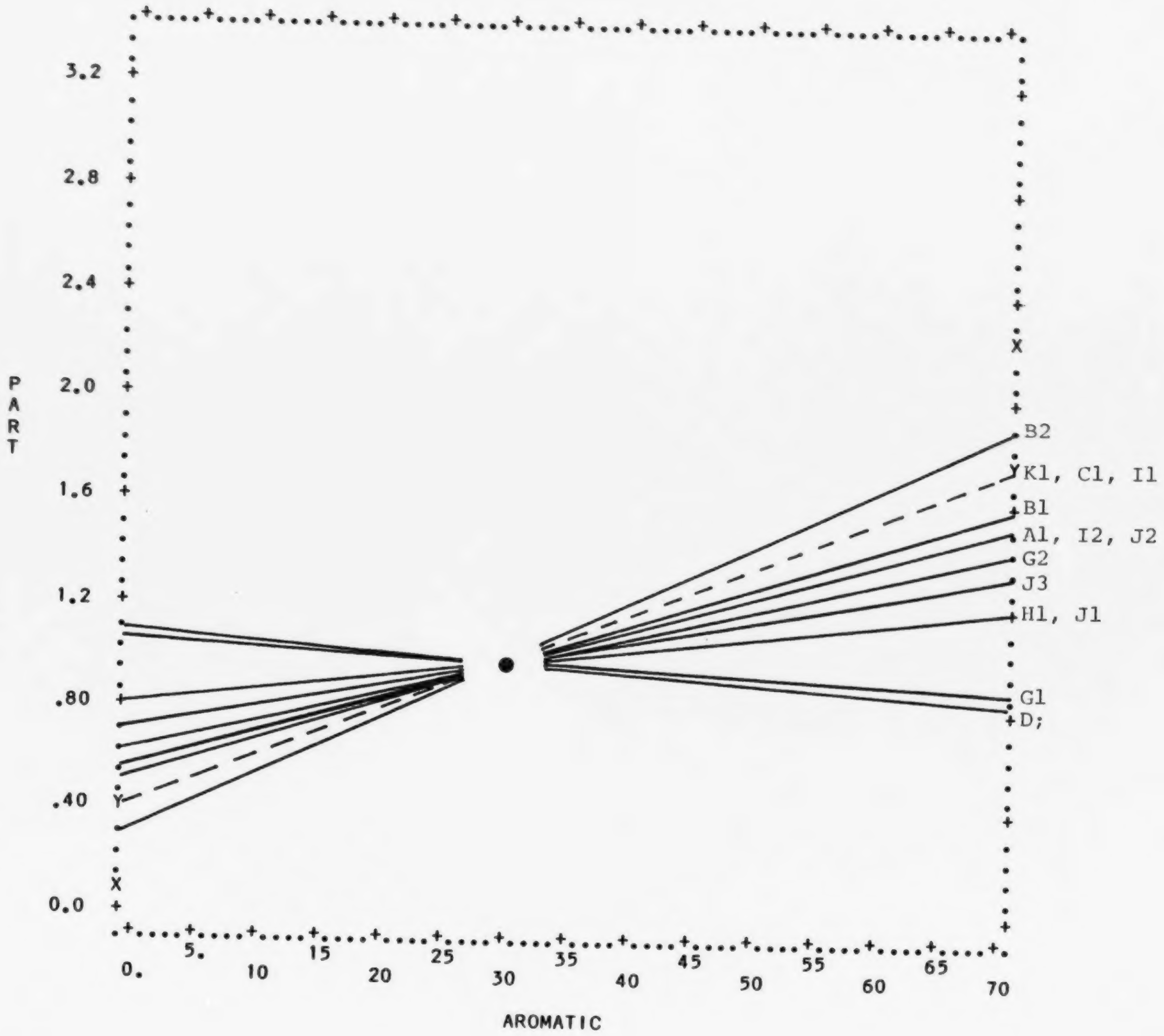
.40
J3
J1
Y
F1
B2
D1
X
C1
X
G1
B1
Y
A1, G2, J2
F2, H1
BPTEN
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320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Y
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B2
YK1, C1, I1
B1
A1, I2, J2
G2
J3
H1, J1
G1
D;
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25
30
35
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45
50
55
60
65
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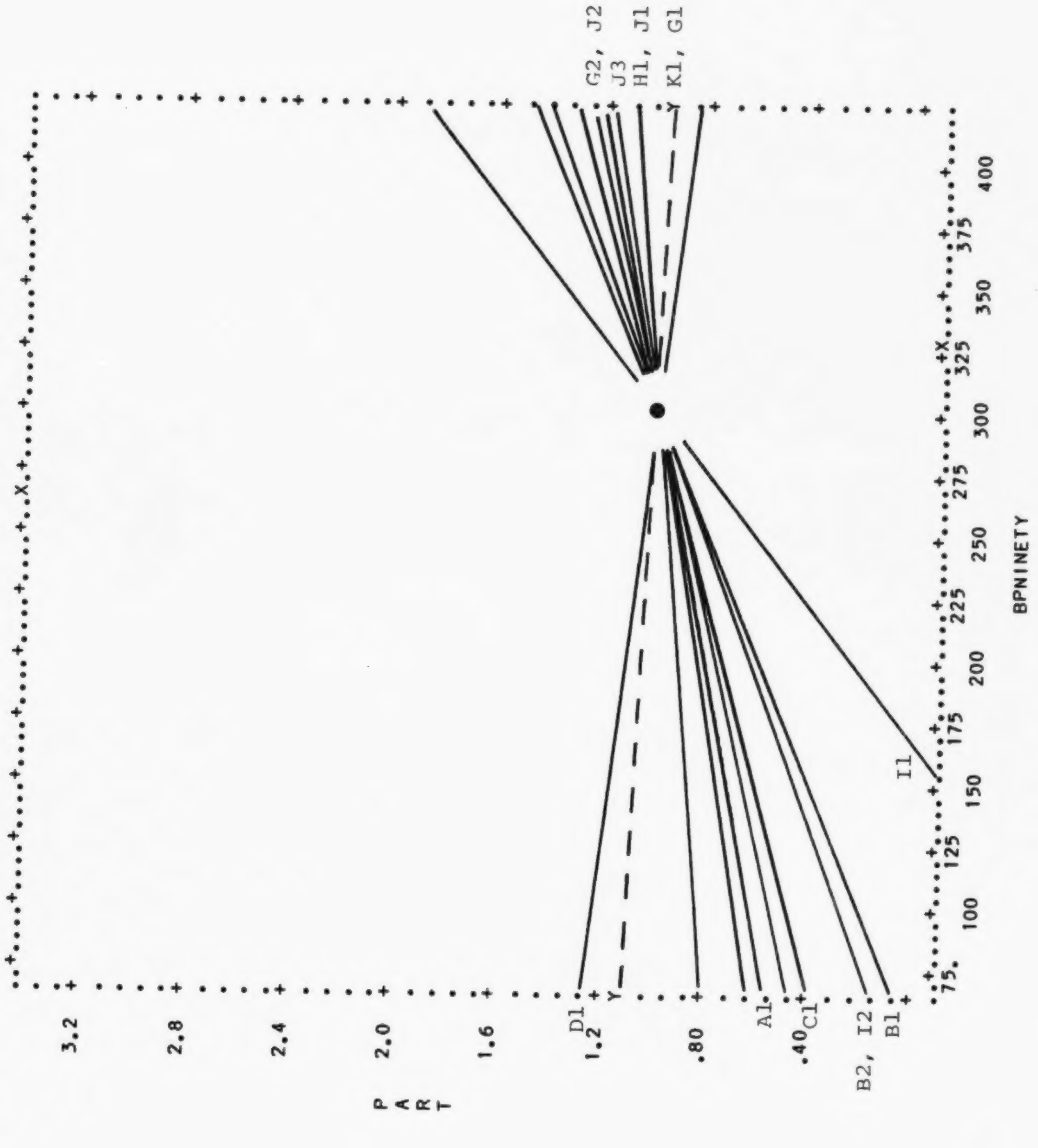
AROMATIC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.40
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A1
C1
B2, I2
B1
I1
G2, J2
J3
H1, J1
Y
K1, G1
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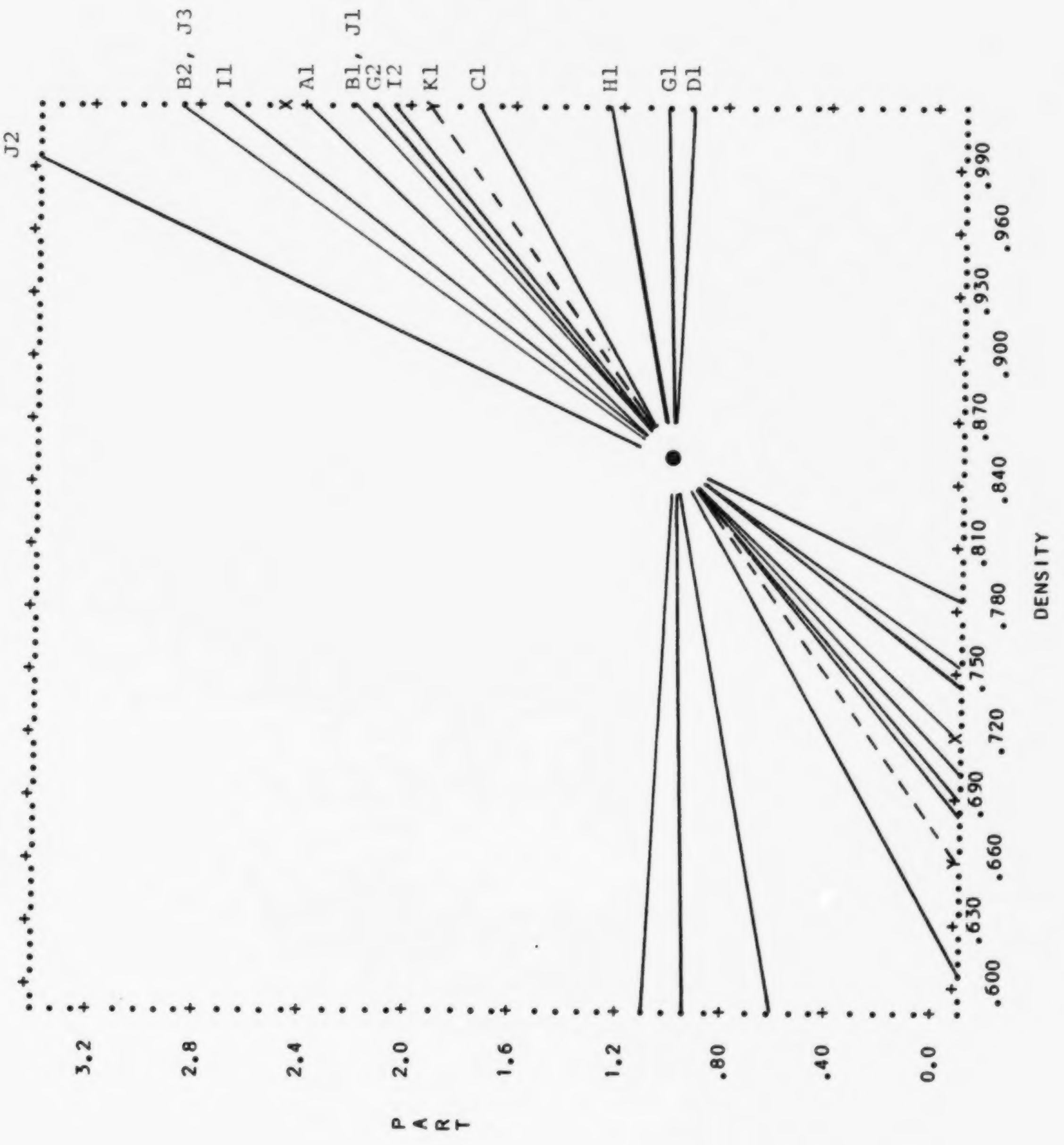
125
150
175
200
225
250
275
300
325
350
375
400
BPNINETY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B1, J1
G2
I2
K1
C1
H1
G1
D1
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Y
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2.8
2.4
2.0
1.6
1.2
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.40
0.0
PART
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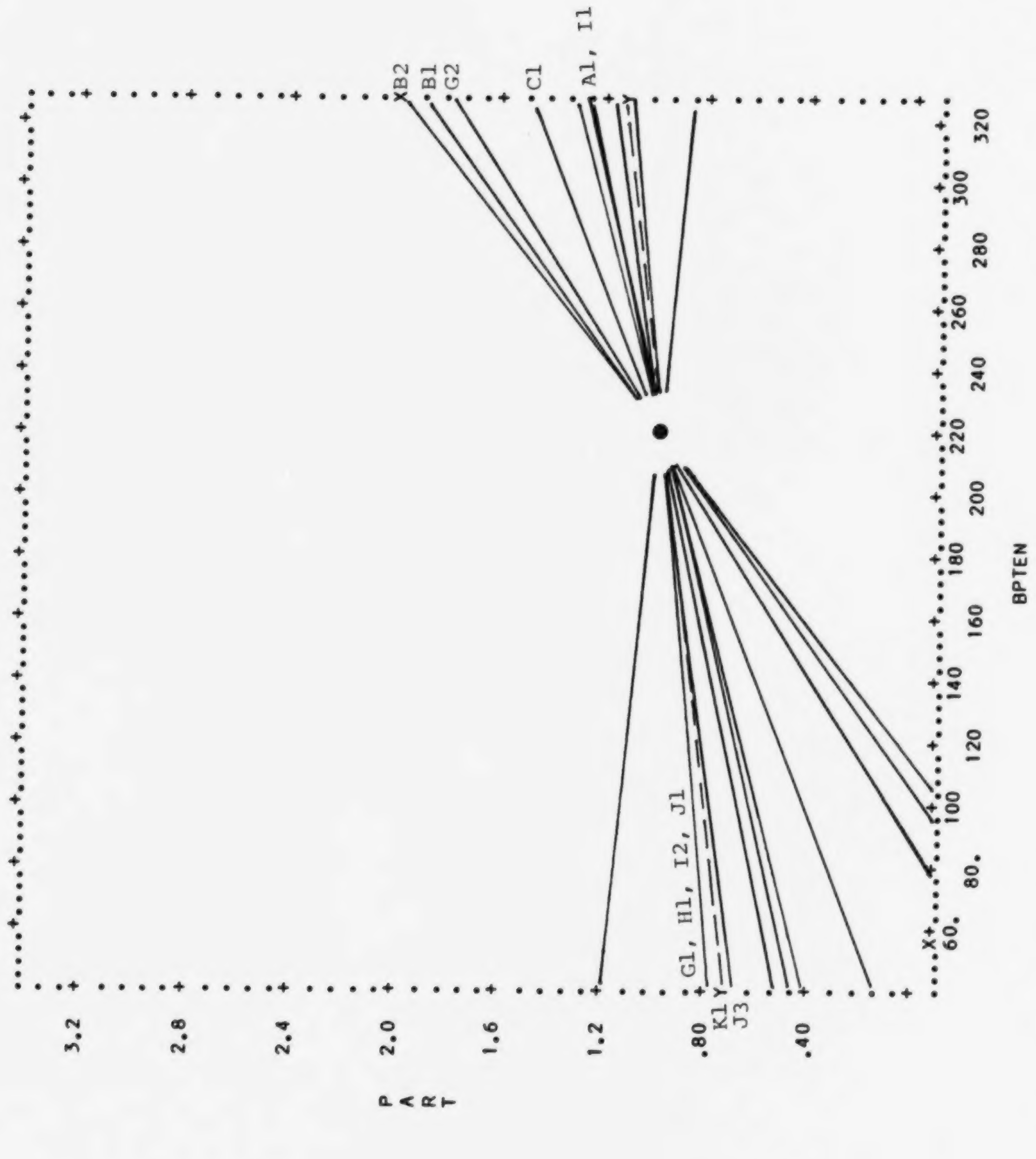
.960
.990
DENSITY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100
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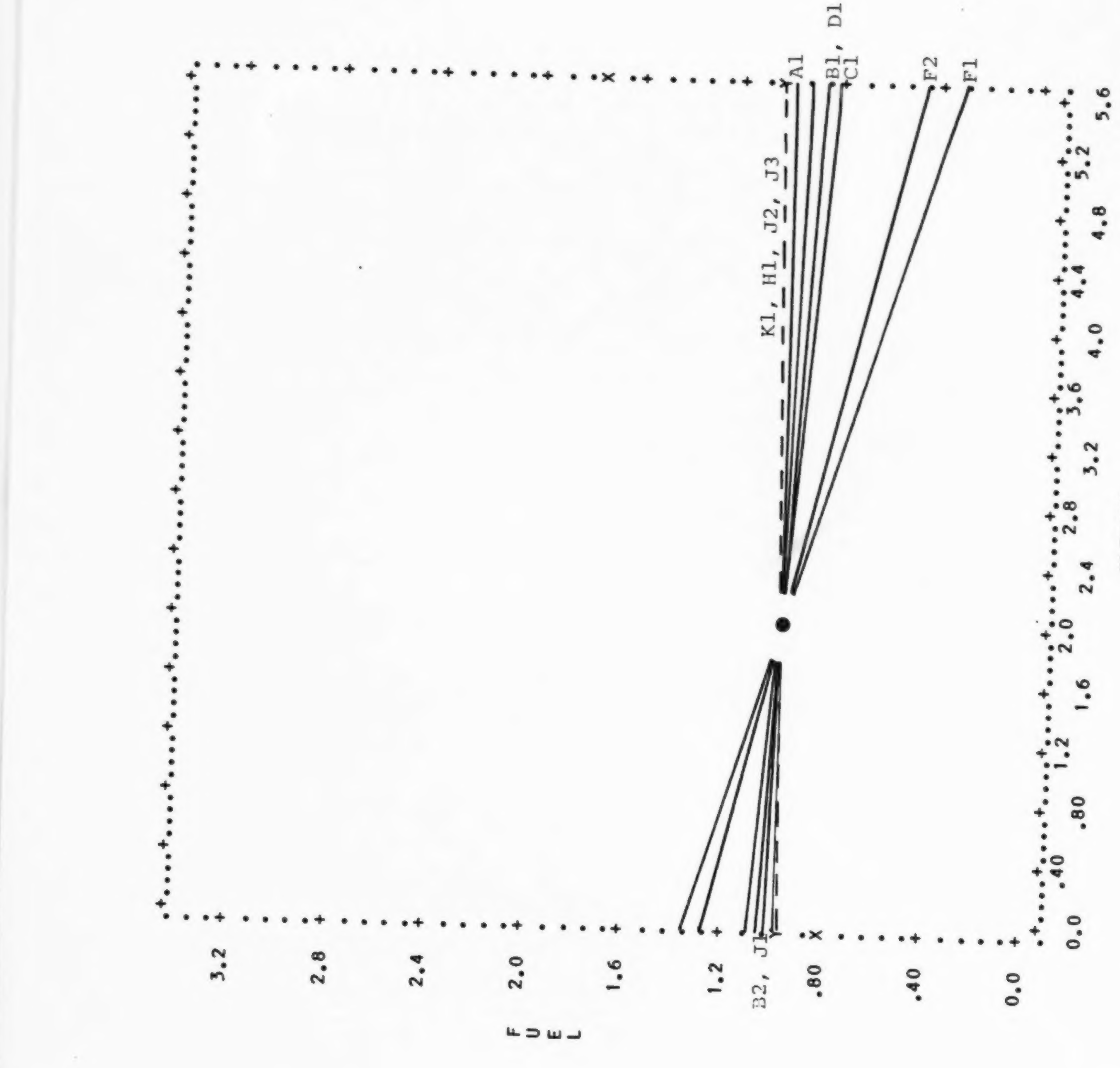
240
260
280
300
320
XB2
B1
G2
C1
A1, I1
G1, H1, I2, J1
K1
Y
J3
X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.80
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1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
K1, H1, J2, J3
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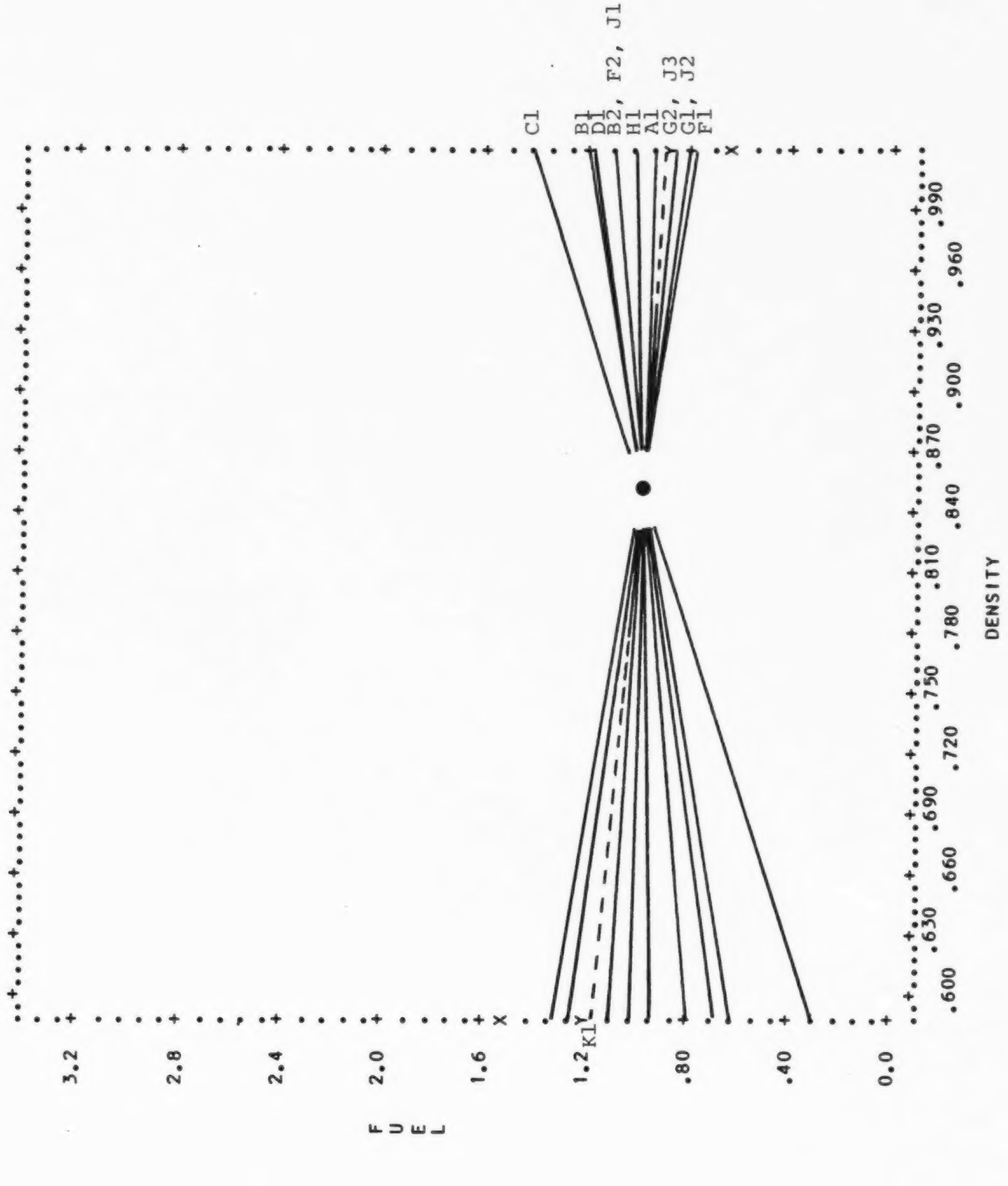
B1, D1
C1
F2
F1
B2, J1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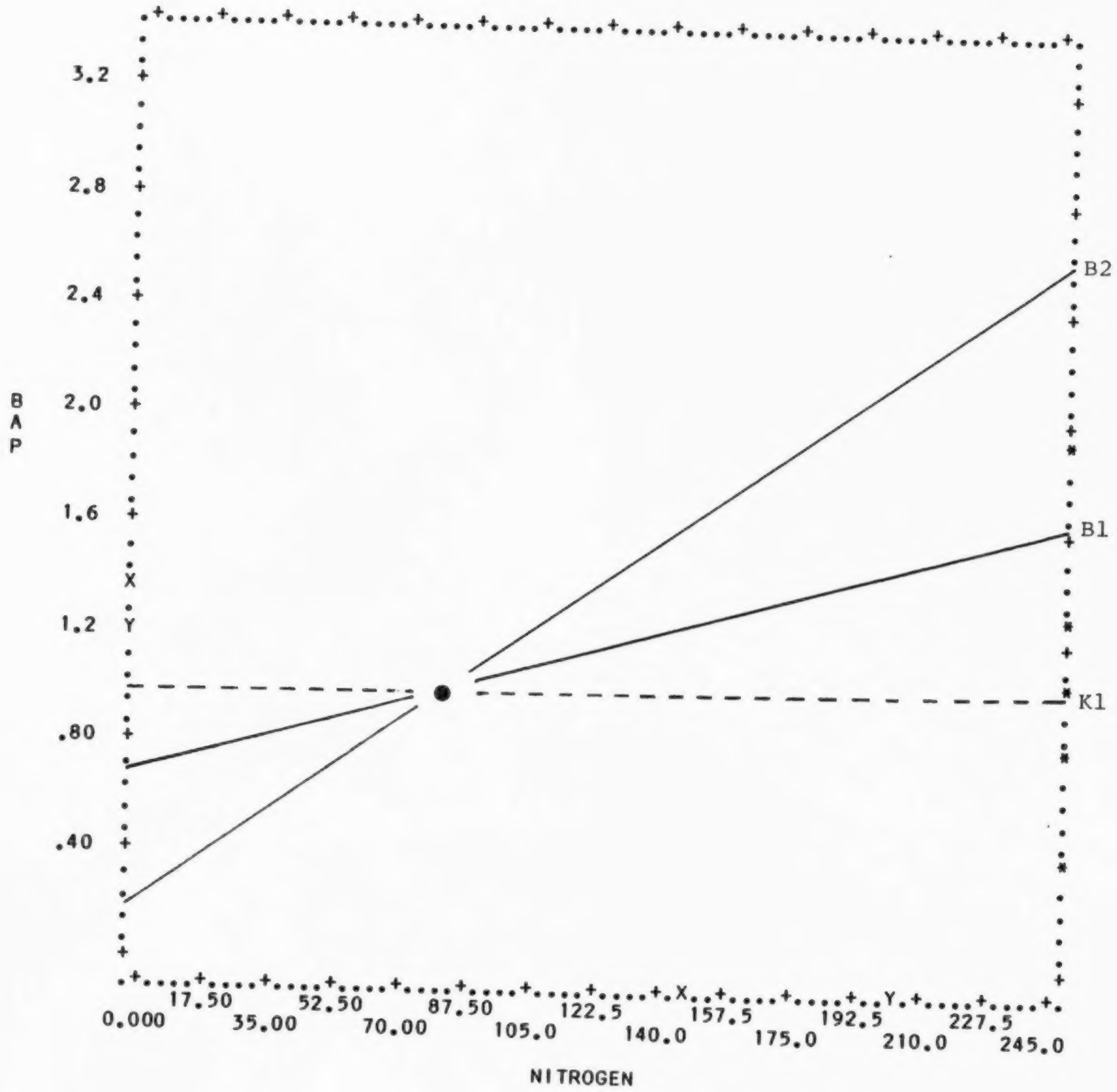
.630
.660
.690
.720
.750
.780
.810
.840
.870
.900
.930
.960
.990
DENSITY
C1
B1
D1
B2, F2, J1
H1
A1
G2, J3
G1, J2
F1
X
Y
K1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1.2
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.40
BAP
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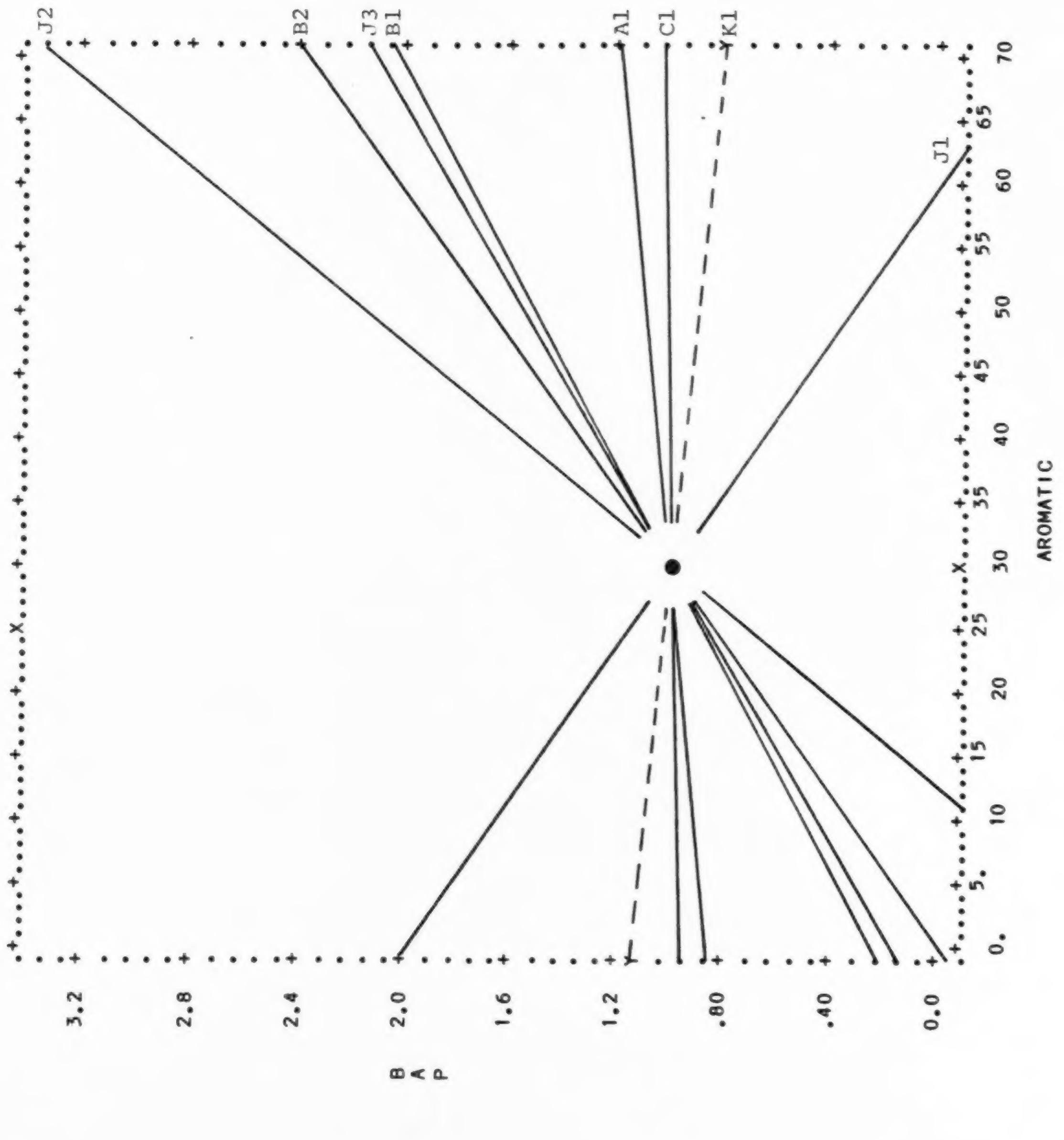
17.50
35.00
52.50
70.00
87.50
105.0
122.5
140.0
157.5
175.0
192.5
210.0
227.5
245.0
NITROGEN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1.2
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.40
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AROMATIC
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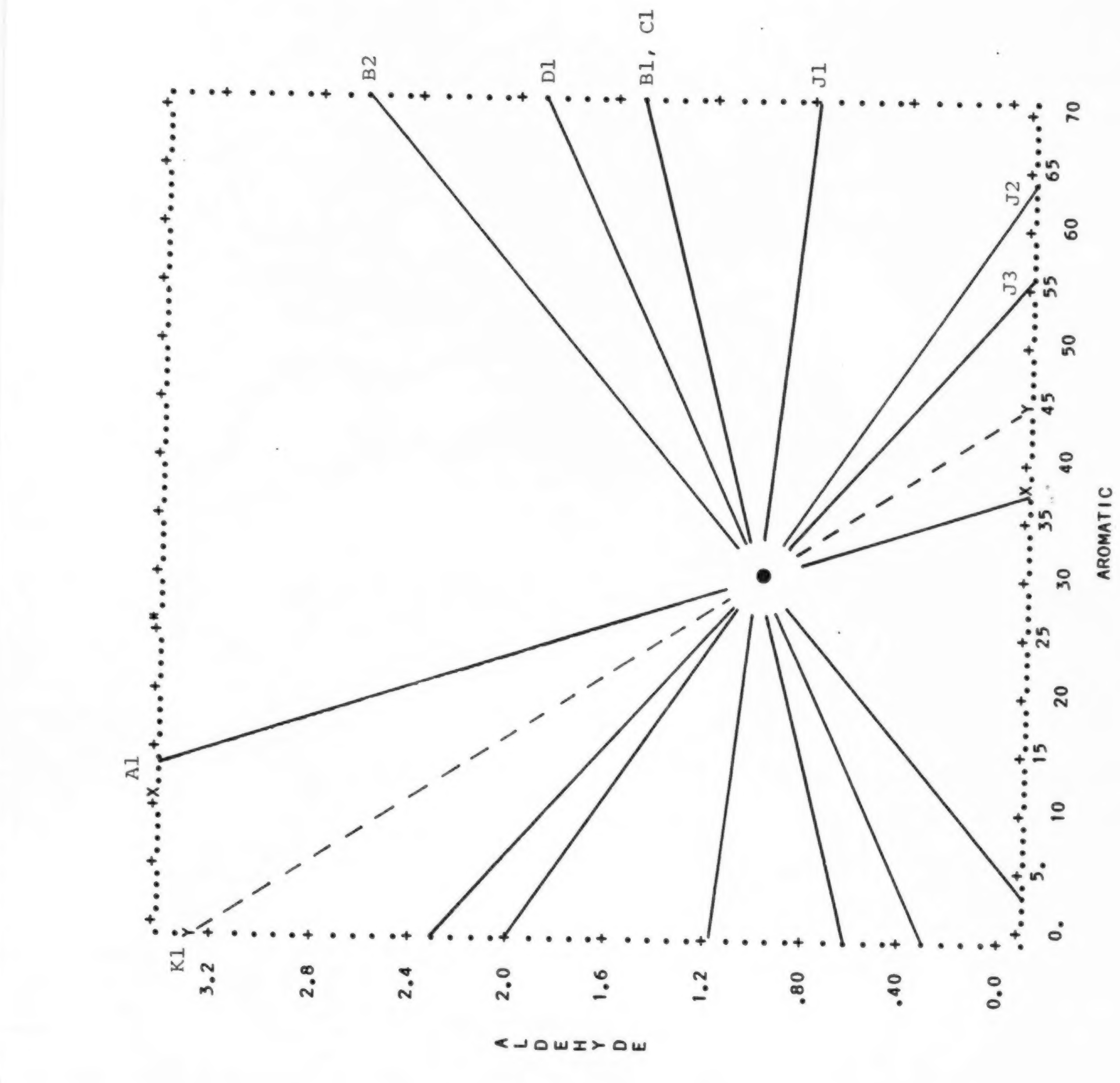
5.
10
15
20
25
30
35
40
45
50
55
60
65
70
J2
B2
J3
B1
A1
C1
K1
J1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B2
D1
B1, C1
J1
J2
J3
X
Y
X
Y
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2.0
1.6
1.2
.80
.40
0.0
ALDEHYDE
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5.
10
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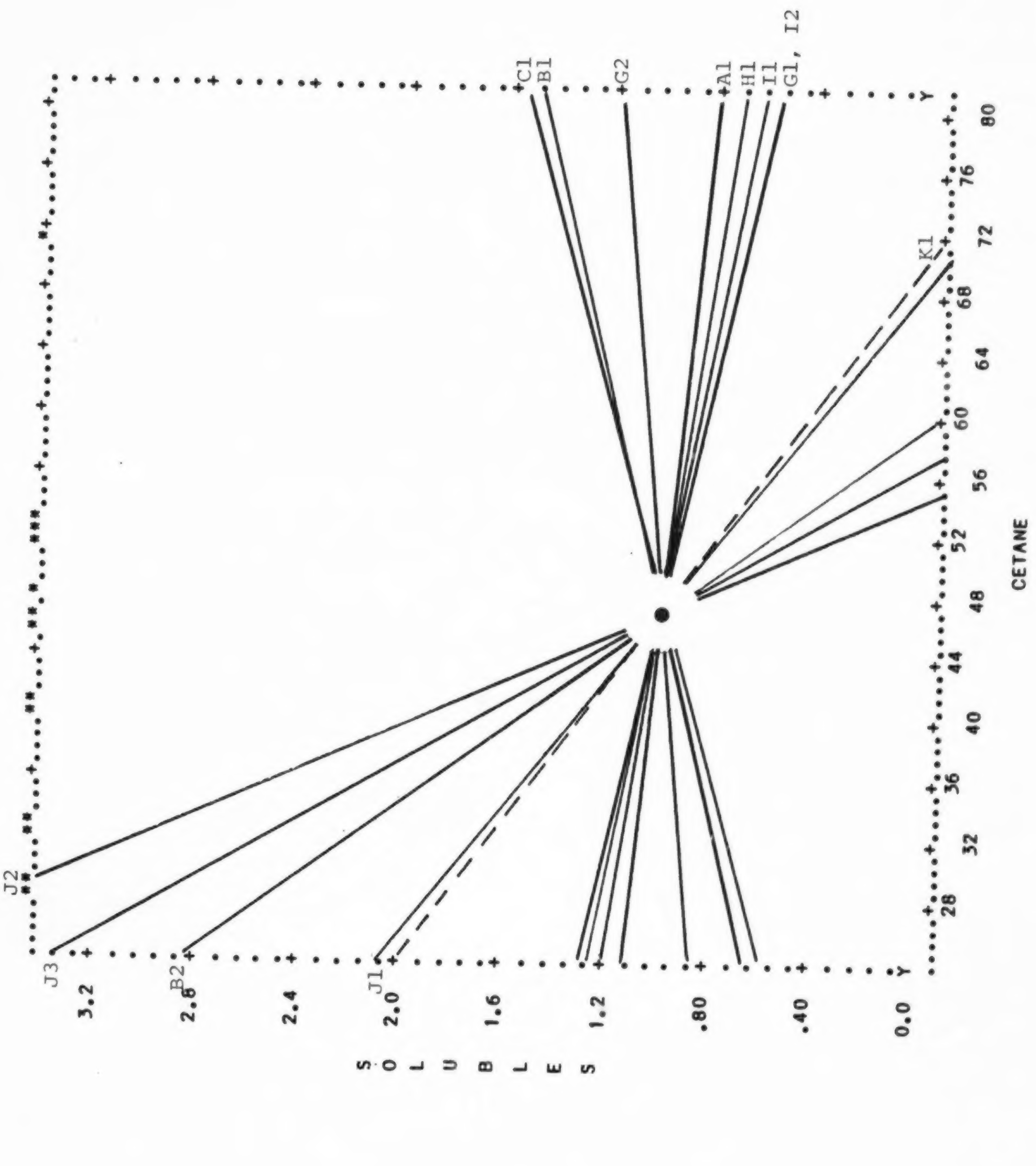
AROMATIC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.80
1.2
1.6
2.0
2.4
2.8
3.2
CETANE
28
32
36
40
44
48
52
56
60
64
68
72
76
80
Y
Y
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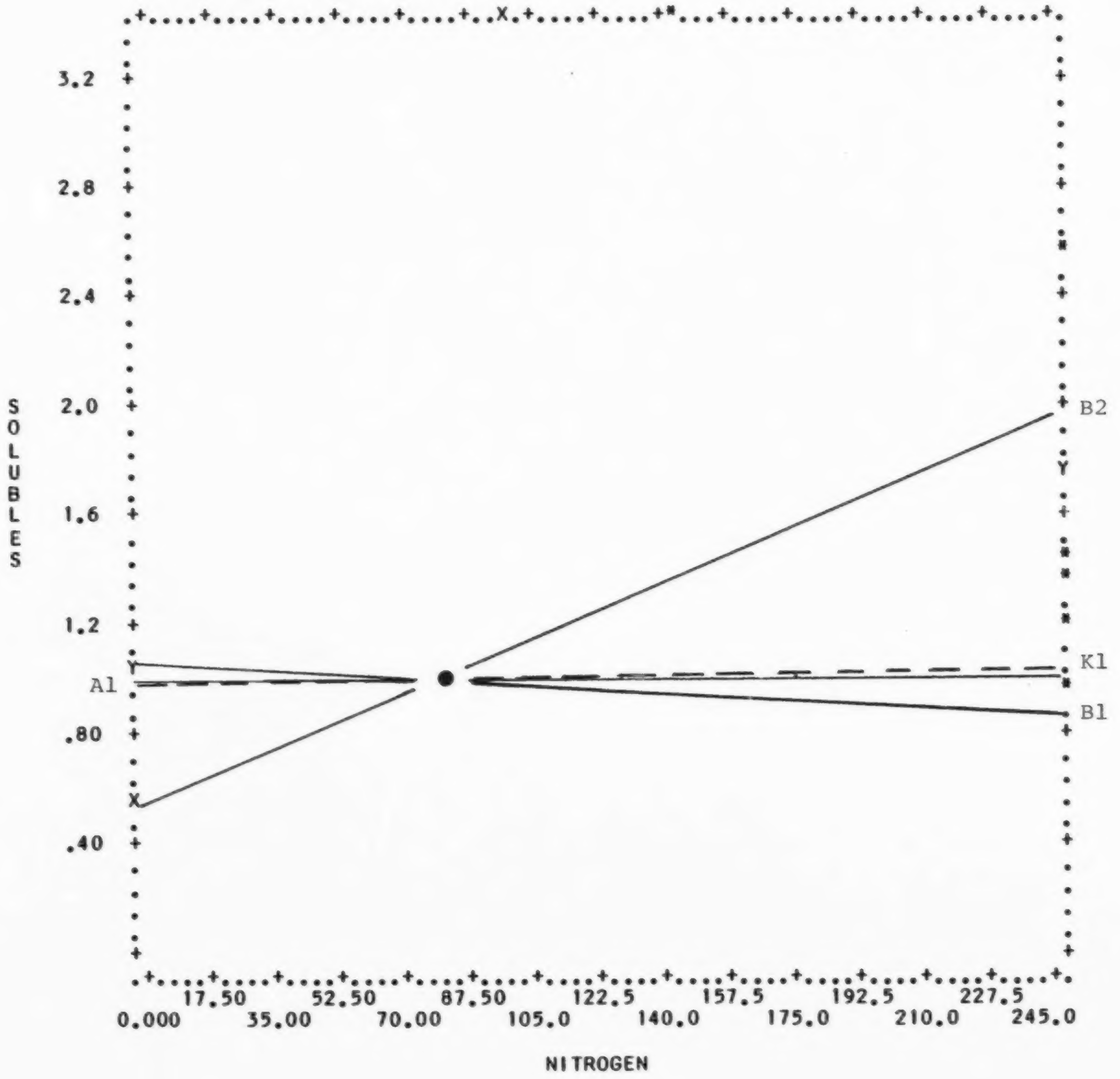
B1
G2
A1
H1
I1
G1, I2
K1
J2
J3
B2
J1



3.2
2.8
2.4
2.0
1.6
1.2
.80
.40
SOLUBLES
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52.50
70.00
87.50
105.0
122.5
140.0
157.5
175.0
192.5
210.0
227.5
245.0
NITROGEN
X
Y
A1
B2
K1
B1